"A COMPARATIVE EVALUATION OF RESULTS OF INTRAMEDULLARY SQUARE NAIL FIXATION VERSUS SMALL FRAGEMENT DYNAMIC COMPRESSION PLATE IN FRACTURES OF BOTH BONES OF FOREARM"

THESIS

FOR

MASTER OF SURGERY
(ORTHOPAEDICS)

BUNDELKHAND UNIVERSITY
JHANSI (U.P.)

2000 **UTKAL GUPTA**

CERTIFICATE

This is to certify that the work entitled "**A COMPARATIVE EVALUATION OF RESULTS OF INTRAMEDULLARY SQUARE NAIL FIXATION VERSUS SMALL FRAGEMENT DYNAMIC COMPRESSION PLATE IN FRACTURES OF BOTH BONES OF FOREARM**", which is being submitted as a thesis for M.S. (Orthopaedics) Examination, 2000, Bundelkhand University, Jhansi, has been carried by Dr. Utkal Gupta under my guidance and supervision. The techniques used in this thesis, were undertaken by the candidate himself, and observations recorded were checked by me from time to time.

Dated : 12-3-2000

R.P. Tripathi

(R.P. Tripathi)
M.S.
Professor,
Department of Orthopaedics,
M.L.B. Medical College,
Jhansi.
(Guide)

CERTIFICATE

This is to certify that the work entitled "**A COMPARATIVE EVALUATION OF RESULTS OF INTRAMEDULLARY SQUARE NAIL FIXATION VERSUS SMALL FRAGEMENT DYNAMIC COMPRESSION PLATE IN FRACTURES OF BOTH BONES OF FOREARM**", which is being submitted as a thesis for M.S. (Orthopaedics) Examination, 2000, Bundelkhand University, Jhansi, has been carried out by Dr. Utkal Gupta in the Department of Orthopaedics, M.L.B. Medical College, Jhansi.

He has put in the necessary stay in the Department as per University regulations.

Dated : 13/3/2000

(P.K. Dabral)
M.S.
Professor and Head,
Department of Orthopaedics,
M.L.B. Medical College,
Jhansi.

ACKNOWLEDGEMENT

It gives me immense emotional gratification in expressing my deep sense of heart felt indebtedness and sincere thanks to my esteemed guide and my respected teacher Dr. R.P. Tripathi, M.S., Professor, Department of Orthopaedics, M.L.B. Medical College, Jhansi. It is very kind of him to have suggested such an interesting topic for my thesis work. With his fatherly attitude, affectionate nature and unfathomed knowledge he always guided me unflinchingly throughout this venture. His expert and suggestions constructive criticism and constant supervision went a long way towards the final shaping of this work.

The fatherly attitude, affectionate nature and always encouraging words of my respected teacher Dr. P.K. Dabral, MS, Professor and Head, Department of Orthopaedics, M.L.B. Medical College, Jhansi, constantly provided me the confidence and enthusiasm so essentially vital to such a project.

I am no less indebted to my respected teacher, Dr. D.K. Gupta, MS, Associate professor, Department of Orthopaedics, M.L.B. Medical College, Jhansi who was always a constant source of encouragement and invaluable support at every stage of this work.

Though the words are not adequate, I take this opportunity to express my deep sense of gratitude to my respected par-

ents, sisters, brother in law and other loving family members for their love and sacrifice, constant encouragement, moral support and guidance throughout my life to make me what I am today.

It is impossible for me to forget the co-operation, unaccountable help and encouragement given to me by my colleagues Dr. Vinod Agrawal, Dr. Amit Singhal and Dr. Anurag Purwar, Sister Incharge, Orthopaedics O.T., Sister Incharge Orthopaedics ward and all the staff members of Orthopaedics Department who had helped me to their best for the completion of this work.

I am thankful to Mr. Vinod Kumar Raikwar for speedy and flawless computer typing of this work manuscript.

In last, but not the least, I am thankful to those patients who were the case material for this study.

Dated : 12-3-2000

(UTKAL GUPTA)

CONTENTS

****

INTRODUCTION

INTRODUCTION

In the modern era of rapidly growing industrialization and high speed traffic, like all the fractures in trauma cases fractures of both bones of forearm are also occuring with increasing incidence. These fractures usually occur in young and middle age population.

The management of forearm fractures has always been a test to the skills of the orthopaedic surgeon. Radius and ulna function as a unit like the two wheels of a cart. Anatomical reduction of both bones, maintaining axial and rotational alignment & complex radial bow, also preserving interosseous space is of vital importance for achieving proper functional results with a good range of supination & pronation, other wise fracture of forearm bones may result in severe loss of function even after adequate fracture healing has occured. Mal union and non union occur frequently due to inherent difficulty in reducing and maintaining reduction of these two parallel bones in presence of pronating and supinating muscles which have angulatory as well as rotational influences on these bones.

Since time immemorial these fractures have been managed by wooden splints and till quite recently by closed reduction and plaster cast application. But despite good technique of closed reduction and plaster cast application an initially undisplaced or perfectly reduced fracture usually gets displaced or angulated while being immobilized in plaster cast resulting in mal union, delayed union and non union. Also prolonged immobilization

required for fracture union results in stiffness of adjoining joints causing poor functional results.

Most of the recent studies have proved that both bone forearm fractures in adults should be given rigid internal fixation after accurate open reduction, maintaining the axial, angulatory and rotational alignment with some form of internal fixation device.

Rigid internal fixation with intra medullary nails or plates and screws is commonly employed which results in early mobilization and excellent functional results. So far Talwalkar's square nail and compression plates with screws have become established as the most commonly used implants for internal fixation of these fractures. The choice between these two usually depends upon experience expertise and personal preference of the operating surgeon.

The aim of present study is to evaluate and compare the results of intramedullary square nailing and dynamic compression plate fixation after open reduction in fractures of both bones of forearm regarding the fracture union, the functional results and their complications.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Mode of injury, age and sex distribution

In most of the cases fractures of both bones of forearm are result of some type of direct blow on the forearm.

Madden et al (1983) in his series of 105 patients reported 75% fractures caused by road accidents 1.85% accident at work, 8.33% sports injury, 7.4% due to other cause.

Shah et al (1988) reported 55.3% fractures caused by road side accidents, 14.7% industrial injuries 16.1% domestic injuries and 13.9% other cause like fall from height or hit by a stick.

By far most common cause is some kind of vehicular accident followed by hit by stick, gunshot wound, fall from height and rarely a pathological fracture.

These fractures occur more commonly in males than females and in age group of third and fourth decade.

In Burnwell and Charnley series (1964) there were 104 men and 46 women and average age was 44.8 years.

In Marek (1961) series the fractures of forearm occured in 23 males and 12 females patients and mean age was 43 years.

Andrianne et al (1984) in his series reported 64.2% males with mean age of 37.4 years.

Relevant Surgical Anatomy

The surgical anatomy of forearm creates problems in its fracture

treatment :

1. The radius and ulna function as a unit. According to study by *Mallin BA,* ulna is a relatively fixed strut around which radius rotates in supination and pronation.

2. In the study of 100 radius bones from cadevers, *Sage (1959)* gave a detailed review of complex anatomy of radius, its medullary canal and its dorsal and radial bows.

3. According to Sage (1963) and Cruess (1973), radius and ulna are joined by supinator, pronator quadratus and pronator teres which along with biceps brachii and forearm flexors exert rotatory and angulatory influence mainly on radius and slighty on ulna.

4. Hatchess and associates (1989) described detailed anatomy of interosseous membrane and stressed on the importance of maintaining this space and the triangular fibrocartilage complex at distal radioulnar joint in forearm bone fractures.

5. Schemitsch and Richards (1992) has confirmed the importance of restoration of radial bow for achieving full pronation and supination after fracture.

Biceps and supinator muscles through their insertion exert supination rotatory force on proximal third of radius. Pronator teres inserting on midshaft and pronator quadratus inserting on distal fourth of shaft, exert pronation as well as angulatory deforming force,

thus causing rotational malalignment of upto 80-100 degree in fractures at different levels through radius. Fractures of ulna are primarily affected by angulatory forces and the proximal fragment angulates towards radius. (Diagrammatic details are on next page)

Historical review of conservative modality of treatment

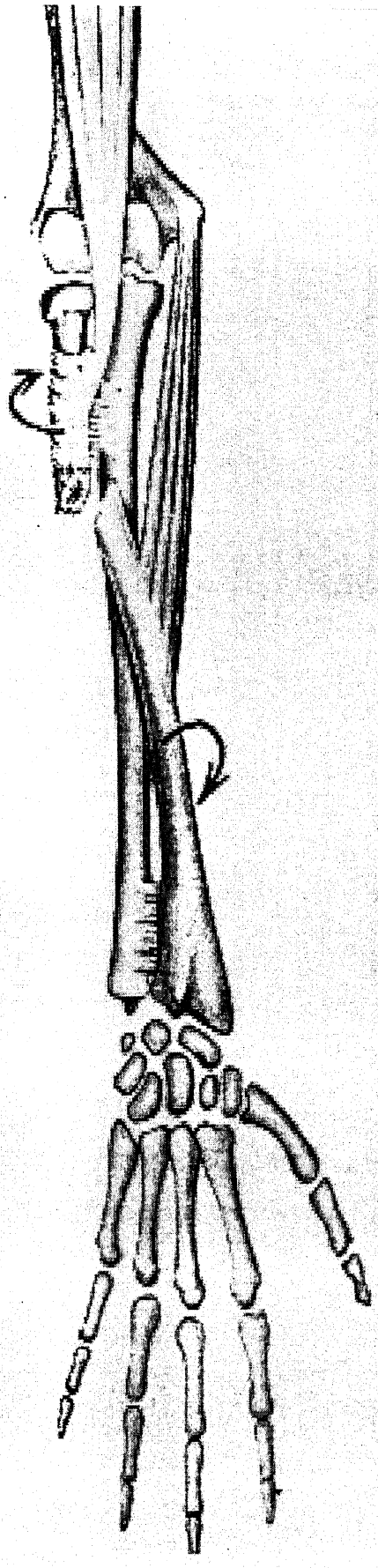
Before the advent of radiography the treatment of forearm fracture was based on correction of clinical deformity followed by application of two short wooden splints with firm pads to preserve their interosseous space with forearm in midprone position.

Plaster of paris although introduced by *Majithsen in (1852)* for various fractures of the body it was not applied to fore-arm injuries due to the fear that rigid encasement might lead to compartment syndrome and ischaemic paralysis.

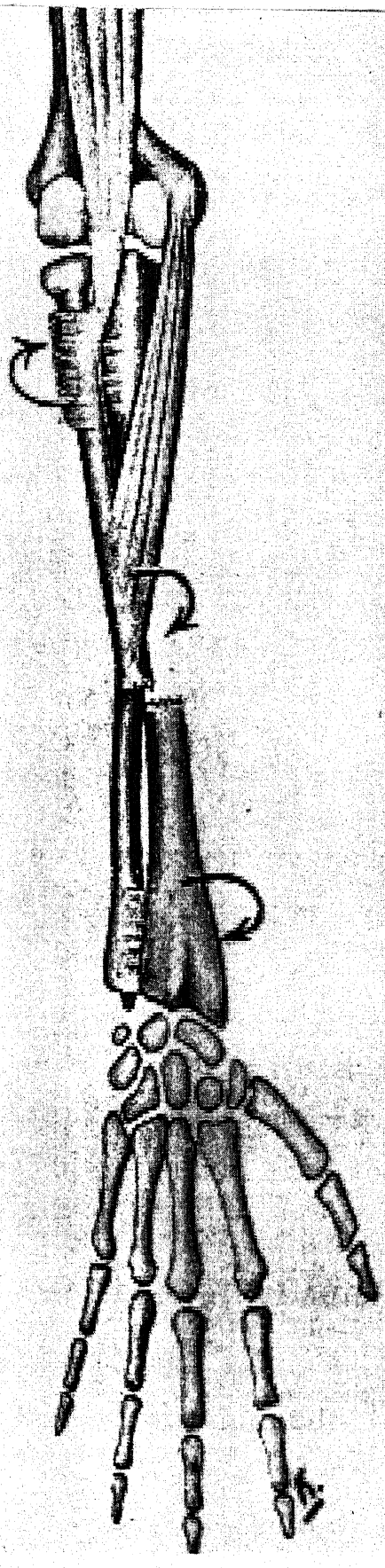
Bohler in (1929) set the example of applying plaster cast after closed reduction in forearm fractures.

Knight and Purvis in (1949) analysed 100 adults with the shaft fractures of both bones of forearm treated at Campbell clinic, of which half had been treated by closed methods. Of those treated by closed methods 71% had unsatisfactory results and incidence of non union and malunion was high.

Holds worth (1949) found that oblique and comminuted fractures of both forearm bones were also unsuitable for conservative treatment.



In a fracture of upper shaft of the radius between the insertion of the supinator & pronater teres, the proximal fragment is supinated & the lower fragment is pronated.



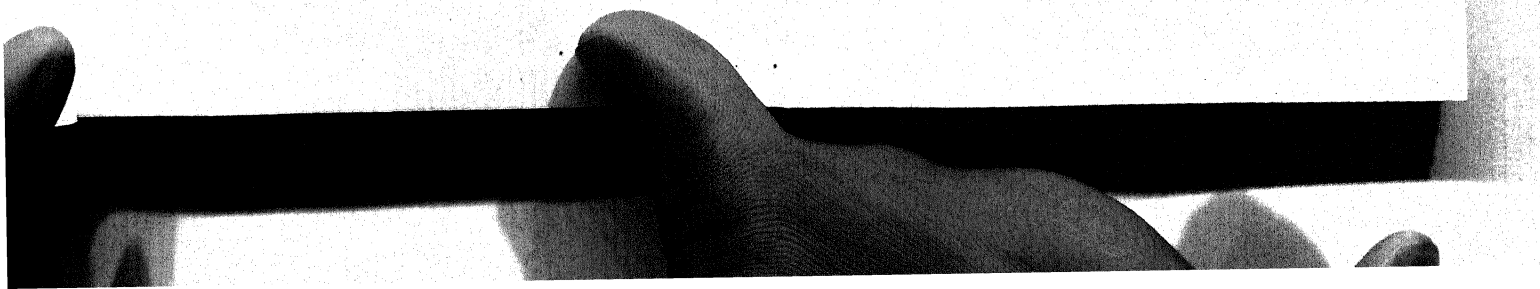
In a fracture of the middle or lower shaft of the radius between the insertion of the pronator teres & the pronator quadratus, the proximal fragment is in mid position (neutral rotation).

In displaced transverse fractures of both bones of forearm it is probable that the closed treatment will fail, the same applies to isolated fractures, displaced or not, in the lower half of the radius or the upper half of ulna *(Smith 1956)*.

Sarameinto and his associates in (1975) reported the use of early functional cast brace for forearm fractures in series of 44 patients with a functional brace below elbow applied at a median time of 18 days after date of injury. Before application of the brace all fractures were manipulated under anesthesia, reduced and immobilized in an above elbow POP cast. The brace permitted flexion and extension at wrist and elbow while limiting supination and pronation. The results were rewarding with only one non union and good functions in majority patients. Sarameinto also found from this study that angular or rotatory deformity of 10° or less resulted in minimal limitations of pronation and supination movements. The fracture healing time in this series averaged at around sixteen weeks. However the excellent results achieved by Sarmiento have not been reported by others.

Development of open reduction and internal fixation techniques

Due to the unpredictable results, hazards and prolonged immobilization various workers studied and experimented with various techniques of internal fixation after open reduction with a variety of implants.



Intramedullary fixation devices and techniques

The use of intramedullary implant for internal fixation was initiated by *Nicholason in (1857)* for fracture of femoral neck. *Heygroves (1918)* developed technique for intramedullary nail fixation in fractures of shaft of long bones.

Lambrinudi in (1939) suggested some principles for intramedullary Kirschner wire fixation of fractures of ulna.

Rush and Rush (1937 and 1939) reported use of a Steinmann pin in the medullary canal of ulna in communited Monteggia fracture dislocation and later devised Rush pins for intramedullary fixation of radius and ulna.

Kuntscher (1940) presented evidence for importance of snugly fitting intramedullary fixation device.

After K-nail fixation got popularized in late 1940's various devices for medullary fixation of radius and ulna were used.

Hermann in (1943) recommended that a bone graft should routinely accompany every form of internal fixation of forearm fractures.

In 1957 Smith and Sage reported a series of 555 fractures collected from all over the country in which some form of intramedullary fixation had been used like Rush pins, Kirschner wires, Stienmann pins, Lottes nails and Kuntscher V-nails. The results were discouraging. Non union resulted in over 20% cases and malunion and poor function were common in those that did unite. Radial

bow was not maintained and use of round pin in medullary canal could not control the rotation of the fragments.

In 1959 Sage published his study of anatomy of radius and introduced Sage triangular foreram nails. The nail for ulna was straight and introduced in a retrograde manner. The nail for radius was bent to aid in maintaining the radial bow. It was introduced from radial styloid. Sage reported good results with his nails. Non union occured in only 6.2% and delayed union in 4.9% fractures. Sage recommended the routine use of autogenous iliac bone grafts. These nails were not recommended for fractures of distal 3rd of radius and when medullary canal was less than 3mm in diameter.

Kuntscher (1959) stated that removal of marrow endosteum and some compact bone due to intramedullary reaming does not lead to any serious problem in fracture healing.

Marek (1961) used snugly fitting resilient straight square nails. The site of insertion in radius was just above the bony prominence of Lister's tubercle. The square shape of these nails prevented any rotation at frature site.To facilitate easy negotiation of square nail for radius, the proximal one inch of radial nail was bevelled and flattened out so that it could bend easily during passage.

Caden (1961) reported a non union rate of 16.6% in forearm fractures treated with Rush pins.

Smith (1963) observed the inversely proportional relationship

between amount of callus and size of nail.

Talwalkar (1964) improvised a rigid solid square nail for a fixation of forearm fractures. The square shape of the nails prevented any rotatory movement at fracture site. The square nail for radius was bevelled at distal tip, so that it could be easily introduced into the medullary canal. The ulnar nail had simple pointed tip. In 1964 he reviewed 80 cases treated by these intra medullary square nails and all fractures united with good functional results.

Anderson (1965) after experiments in dogs found that union of a fracture treated by medullary nailing is almost exclusively periosteal because reaming of the medullary canal and insertion of nail destroys the blood supply of inner two third of contex for the entire length of the nail. The damage of this blood supply and the presence of nail prevent the formation of endosteal callus. Union therefore takes place by bone formation in fracture hematoma.

If the nail is snuggly fitting, union occurs promply and minimal periosteal callus is formed. In absence of motion the capillaries abundant blood supply in organizing hematoma and new bone forms without going through cartilagenous phase whereas when the nail is loose, bone formation in fracture hematoma occurs through the process of endochondral ossification by cartilage formation.

Cotler and associates (1971) used Schnieder nailing for fixa-

tion of unstable forearm fractures. More than 94% patients had excellent fuctional results.

Sisk (1980) states that satisfactory stabilization of a fracture by medullary fixation is possible under the following circumstances:

1. When the fracture occurs through the narrowest part of medullary canal, the intramedullary fixation gives stable fixation counteracting the angulatory shearing as well as rotational deforming forces. If the medullary canal in one fragment is much larger in one fragment than in other, poor control of rotational forces frequently results.

2. When the canal is curved a straight nail can still be used. Fixation is obtained at the end of nail and at the apex of curve in the bone. In these cases a resilient stainless steel nail is useful which is deflected by the cortex at one or more points of contact.

James (1981) found that delay in biomechanical maturation of callus occurs in a fracture treated by intramedullary nail as compared to that with compression plate. The delay may reflect an inhibition of formation of endosteal callus. But once union is achieved, the bio mechanical quality of union similar after compression plate or intramedullary nail fixation.

Internal fixation modality with plates and screws

In early 1900's Lane in London and *Lembotte 1907* in Belgium reported the use of plates and screws for treating diaphyseal fractures.

Unfortunately, failures were frequent due to metal reaction, infection and inadequate design of fixation devices.

The effectiveness of fixation was sometime impaired by electrolytic changes around metallic plates and screws. This difficulty was overcome by the introduction of vanadium steel plates in *1913 by Shermen.*

It was after the work of *Venable and associates in 1937* on electrolysis and presence of metal inside body, that better and relatively inert molybdenum steel and later cobalt chromium alloy steel were developed for manufacturing the implants.

Campell and Boyd in 1941 used autogenous tibial grafts fixed to radius and ulna with bone pegs or screws for acute fractures as well as non unions but the grafts often developed fatigue fractures before they were revascularized.

Even after better metals became available many of the early plates used for fractures of radius and ulna were poorly designed. Thus, failure were very frequent and the use of plates and screws fell into disfavour.

Danis (1949) was the first to give the idea of using active compression with the help of specially improvised plates with a coapting screw at one end through which compression was applied . He observed that with this longitudinal compression system fracture was healed with very little peripheral callus, a phenomenon, which he referred to as "primary fracture healing".

Eggers and associates in (1951) introduced "slotted plate" or "contact splint". The plate was designed with slots rather than round holes. Eggers plate was much stronger than those used previously and with this plate, plate and screws slowly started gaining favour.

Venable CS (1951) also discovered an impacting bone plate to achieve close coaptation.

Boreau and Hermen (1952) introduced a plate with two parts in which a cylindrical bolt forced the fragments together.

Bagby and Janes (1958) modified a "collison plate" with oval holes allowing compression to be achieved by eccentric placement of the screws.

Jinkins and Coworkers (1960) reported a series of 165 fore-arm fractures in which 145 slotted plates and 20 medullary nails had been used. Overall non union rate was only 4.2%. They concluded that results were best when slotted plate was used for ulna and a slotted plate or rush pin was used for radius.

Hadden (1961) observed 212 fractures of the forearm of which 157 were treated with intramedullary rush pins, 40 with Eggers slotted plate and remaining with four hole plates. The results with Egger's plate were amazingly good where incidence of non union was 7.5%, whereas with rush pins incidence of non union was 16.6%. The cases treated with four hole plates had 40% incidence of non union.

Hicks (1961) reported a series of forearm fractures treated by open reduction and rigid internal fixation with special "Lug-plates" without use of supporting plaster and reported six percent non union.

Muller along with Allgover and Willeneger designed a compression device in 1958, but the work was published a few years later in 1961. This removable compression device was used originally with rigid 4.5mm 4 hole plates but later it was used with rigid plates of various sizes and types . It soon became very popular and was known as AISF (AO) compression plate which is used even nowdays.

De Buren (1961) treated cases of non union in radius and ulna and achieved bony union in 80% cases in 16 weeks.

Burnell and Charnley (1964) reviewed 218 fractures of the shaft of radius and ulna by standard Burn or Shermen plates from one and a half to seven inches long and number of screws varied from 2 to 8. In 197 cases there was fracture union in an average time of 20 weeks and there were 21 cases of non union. Out of 176 patients with union and intact fixation, functional results regarding supination pronation and adjoining joint movements were excellent in 69.8%, good in 15.5%, fair in 13.8% and poor in 0.8% cases.

The plates were removed in 17 cases. Two were removed for pain, six for sepsis, two for failure of fixation, one for breakage, two during scar excision, one for subcutaneous promi-

nence and two for unexplained reasons. Posterior interosseous nerve was damaged in one fracture where radius was exposed by Thompson's approach in its upper half.

Anderson (1965) noted in fractures treated with rigid fixation by plates and screws, the endosteal callus forms first and an outgrowth of callus from medullary canal fills space between cortical ends and unites them. Peripheral bone formation from periosteum and fracture hematoma is not prominent.

Sargent and Teipner (1965) reported primary bone union in 100% of fresh fractures treated by double plate method without bone grafting. The functional results were excellent in 91% of cases. The remaining 9%, lacked only 10% of any motion.

Ritchie (1968) reported results of treating 33 forearm fractures with "Hick's plates". In 26 cases good functional results were achieved, rest 5 were with in 50% of normal functions.

Baker et al (1969) treated 72 patients by long 6 & 8 hole slotted plates. Satisfactory function was achieved in 68 patients. Four cases went into non union.

Naiman et al (1970) reported 100% union in a series of fractures of isolated radius or ulna treated by compression plates.

The concept of "dynamic self compressing plate" was first described by *Bagby (1957, 1968)* and *Denham (1969)* but it was developed with full technical details by *Allgover et al (1970)*. This plate could be used as compression plate, tension band plate

and buttress plates.

The disadvantages of AISF compresion device were overcome by this "Dynamic Compression plate" or "D.C.P". The difficulties with AISF compression device were :

1. A seperate compression device was required.
2. Long incision and extensive dissection was necessary.
3. Round screw hole with closed conical fit of screw heads made it difficult to position screw in any required oblique position.
4. Very rigid fixation led to stress protection and fatigue fracture related to osteopenia of the adjacent bone.

Experiments as well as clinical studies have proved distinct advantage of DCP over other compression plates.

Dodge and Cady (1972) reviewed primary compression plating procedure in 78 patients with forearm fractures and reported loss of fixation in 5%, corrosion of implant in 13%, post operative sepsis in 13%, refracture in 1%, transient neuropathy of superficial radial nerve in 10% and loss of motion in 22%.

Petxie and Tile (1972) reviewed 39 cases, 27 had closed and 12 had open fractures. In all cases early open reduction and AISF compression plate fixation was carried out, post operative plaster splint fixation was used only until wound healed, which resulted in good functional results.

Sisk (1975) suggested to apply autogenous iliac grafts when comminution involves more than one third of the circumference of the bone. Grafts should not be placed on the interosseous border of the bone or it may lead to cross union (synostosis) or limited rotation.

Anderson (1975) reviewed 193 fractures of radius and 137 fractures of ulna treated by compresion plate. 25.9% of cases with severly comminuted fractures had iliac bone grafts and found overall rate of union 97.9% for radius and 96.3% for ulna. The average time for union was 7.4 weeks. Functions were good in 85% and unsatisfactory in 15% of cases.

Anderson suggested that four hole compression plates may be suitable for non communited transverse fractures. Five and six hole plates should be used if there is significant communication or obliquity in plane of fractures. He also suggested that plates should be placed anteriorly or posteriorly selecting the surface on which it fits best. Placing plate on compression side has not produced any problem. Plate should be placed on the side of comminution as the plate stabilizes the loose fragments. He defined the union of a fracture when there was obliteration of fracture line and presence of bridging trabeculae between two fragments.

Mckibbin (1978) from animal experiments found out that less rigid plate with a Young's modulus that nearly approximates that of the bone will give better results. Titanium with Young's modulus half that of stainless steel is the most suitable metal

for manufacturing plates and other implants.

Whiteside et al (1978) suggested that placing the plate on the periosteum rather than on bone produces greater blood supply alteration then exposure that strips the periosteum with the muscle attached. Thus, the periosteum should be stripped sparingly with periosteal elevator, just sufficient for the application plate.

AISF in 1979 in its mannual of internal fixation recommends that at least five cortex purchase on each side of main fragment is necessary for rigid fixation in forearm bones. Also that, screws inserted too close to the fracture may split the bone. And, a plate longer than necessary is better than one that is too short.

Grace and Eversmann (1980) analysed 92 acute diaphyseal fractures of the forearm treated with plates and screws. The effect of early active postoperative movements was studied. Patients with open fractures and those with both bone fractures lost significant rotation of the forearm, irrespective of the treatment given. A programme of early active movement without external mobilization increased the range of movements of forearm in patients with fractures of both bones of forearm.

Rand et al (1981) compared the effect of open intramedullary nailing and compresion plate fixation on the fracture union and concluded that :

i. Fractures fixed with intramedullary rods displayed higher values for whole bone and fracture site blood flow and for a longer time, reflecting a compensatory phenomenon to the blockage of endosteal blood supply for intramedullary rod. This was not found in compression plate fixation.

ii. Fractures with intramedullary rod fixation show more periosteal callus and less endosteal callus as compared to compression plate fixation.

iii. Fracture union was delayed in medullary fixation as compared with plate fixation.

iv. Osteopenia of adjacent bone due to stress protection was similar in both cases.

v. Delay in maturation of fracture union regarding its tensile strength in medullary fixation is found due to lack of endosteal callus formation.

vi. Union was delayed in presence of a loose intramedullary nail.

In 1981 Rosacker and Kopta reported 54 patients with bone fracture treated by various fixation devices like, conventional plates and intramedullary rods. They found that single most important factor associated with excellent union and functional result was the adequacy of reduction. And the best anatomical reduction were achieved in fixation with compression plates as it was difficult to apply these compression plates with suboptimal reduction. They also found that delayed surgery for about 1

to 3 weeks were favourable in attaining good primary bony union. However prolonged delay caused a reduction of quality of functional results as range of movements were gradually lost.

Klaue and Perren in 1982 developed the "dynamic compression unit" (D.C.U.) type of fixation plate. These plates had evenly placed symmetric screw holes with oblique undercuts for improved range of inclination.

Hadden et al (1983) used A.O.D.C.P. fixation in 111 fractures in 108 individuals with 24% having open fractures. After 3 years they reported 97% cases with strong union and satisfactory fuctions in 80% cases. Their choice of implant was "Small fragment dynamic compression plates". Seven patients developed operative nerve injuries.

Hidakas and Gustilo (1984) removed 32 plates. The interval between plate application and removal ranged from 8 to 62 months. Seven refractures occured between 2 and 4 weeks after plate removal. No refractures occurred more than 40 weeeks after plate removal. They advice at least 6 weeks plaster cast immobilization after plate removal.

Anderson and Bacastow (1984) treated forearm fractures with compression plates and reported 98.4% union. Average time of union was 8 weeks.

Vainiopaa et al (1987) treated 14 children of fractures of both bones of forearm by open reduction and internal fixation. Only

four patients complained of pain or awareness of restricted movement. Limited pronation supination movements were associated with fractures of proximal third of forearm or due to shortening of ulna.

Shah et al (1988) reviewed 134 patients treated with small fragment dynamic compression plate fixation for both bone fractures. According to Anderson's criteria he achieved 86.6% excellent results, 6.7% satisfactory, 3.8% unsatisfactory and 2.9% poor results. He stated that fracture of forearm bones should be considered intra articular fractures and must be treated with open reduction and rigid internal fixation.

Sisk (1988) pointed out that plates and screws are especially useful for fractures of distal third or proximal fourth of radial shaft and proximal third of ulna.

Chapman et al (1989) reported no refractures after plate removal in 117 fractures when 3.5 mm AO. D.C.P. were used. However plate removal in three patients fixed with 4.5mm D.C.P. plates resulted in refracture in two of them.

Perren et al (1989) developed "L.C.-D.C.P." or "limited contact- Dynamic compression plate" as a further developemnt of Dynamic compression unit or D.C.U. This L.C.-D.C.P. has some definitive advantages over D.C.P. and it complied with the concept of biological fixation. Symmetric arrangement of screw holes without solid elongation between innermost screw holes and two sloped cylinder on either side in the screw hole made the placement of plate in complex fractures easier. Lateral

cuts on the under surface caused less damage to periosteal blood supply and allowed callus and bone formation on the under surface (which is usually the tension side) of the plate as compared to flat undersurface D.C.P.

Deformation of plate holes during plate bending was kept minimal as the holes were protected by flexible cross section between holes. Due to trapezoid cross section and lateral undercuts, there was minimal defect in fracture healing on the undersurface and lateral sides of the plate and this helped in minimizing the chances of refracture after plate removal.

Bednar and Grandwiewisky (1992) suggested that plate removal must not be done before two years after application of plate, so that changes of refracture after plate removal could be minimized.

Schemitsch and Richards (1992) observed 55 patients of both bone forearm fractures treated with D.C.P. fixation. Extensive follow up was done for mean 6 years with functional and radiographic assessment. 84% patients achieved excellent or satisfactory results. Bone grafting did not affect the rate of union according to chi square test. A good functional result (>80% of normal forearm rotation) was associated with restoration of the normal amount and location of radial bow. Similarly return of grip strength was related to the restoration of normal radial bow.

MATERIAL AND METHODS

MATERIAL AND METHODS

This study was conducted in the department of orthopaedic surgery M.L.B. Medical college and Hospital Jhansi. The cases for present study were selected from the patients attending emergency as well as the outpatients department of orthopaedics from March 98 to January 2000. A total of eighteen cases are being included in this study.

Patients were selected for this study based on the following criteria :

1. Fractures of both bones of forearm.
2. Age more than 17 years or past the age of skeletal maturity.

Following types of cases were not considered suitable for the study :-

1. Unsuitable condition of neighbouring skin, like presence of infection, burns, abrasions or blebs.
2. Poor anesthetic and surgical risk.

Each patient after admission in this hospital was subjected to careful and detailed history with special reference to the following :

* Name
* Age

* Sex
* Occupation
* Mode of injury
* Date and time of injury
* Associated injuries
* Treatment, if any, taken before coming to this hospital and their results.

Then all patients were examined clinically and the following points were noted :

* Side involved
* Amount of swelling
* Deformity
* Site of fracture
* Any wound communicating with fracture
* Any neurovascular involvement
* Presence of any associated injury
* Local examination of the forearm skin with special reference to the condition of skin.
* Condition of wound

In addition, general examination, relevant systemic examination was also done in every case. All the cases were subjected

to radiological examination (antero posterior and lateral view of affected forearm with wrist and elbow joint). Other different parts of body in which fracture was suspected was also radiologically examined. Every patient was subjected to necessary pathological investigations and preanesthetic check up was done. As soon as the patient was medically fit for operation, the operation was done.

Either of the two appliances were used for internal fixation after open reduction :

(a) Dynamic compression plate.

(b) Talwalkar's square nail for radius and ulna.

Instruments and implants required specially for carrying out the procedure other than the general orthopaedic surgery instruments were :

1. Small fragment Dynamic compression plate of six, seven or eight holes.
2. 3.5mm cortical screws of different lengths from 8 to 24mm.
3. A.O. type bone holding clamps.
4. 2.5mm & 3.2mm drill bits and hand drill machine.
5. 3.5mm drill guide, bone tap, tap sleeve and hexagonal screw driver.
6. Complete set of radial and ulnar square nails of width varying from 1.5mm to 4mm with 0.5mm increments and lengths

varying from 16cm to 30cm with 1cm increments.

7. A set of forearm reamers, extractor hooks and a small size bone awl.

The implants used were the same for both bones. Autogeneous iliac bone grafts were used when comminution was significant or where fracture was more than three weeks old and they were applied away from interosseous border.

OPERATIVE PROCEDURE

After giving suitable anesthesia (general anesthesia or brachial block anesthesia) the pneumatic tourniquet was applied. In certain cases where operation was prolonged for more than 90min the tourniquet was released and was not applied again. Then, after painting and draping with patient in supine position, the fracture sites of radius and ulna were exposed by their respective operative approaches.

Radius

When fracture was in the distal 2/3rd of the bone Anterior or Henry's approach was used and plate was applied on the broad, flat volar aspect of radius which is well covered with soft tissues.

In this approach, with forearm in supination a 10-15cm longitudinal incision was made over the interval between brachio radialis and flexor calpi radialis muscles. The sensory branch of radial nerve lying beneath branchioradialis was identified

and retracted laterally with it. The flexor calpi radials tendon and radial vessels were retracted medially. Beneath this flexor pollicis longus and prorator quadratus muscles were retracted medially by subperiosteal dissection along with overlying flexor digitorum superficialis muscle and thus the fracture site was exposed.

In fractures through proximal 1/3rd of radius, Thompson's dorsal approach was used and plate was applied on the dorsal surface. In this approach, with forearm in pronation a skin incision was made over proximal radius along a line joining centre of dorsum of wrist to a point 1.5cm anterior to the lateral epicondyle of humerus. Deep dissection was done to create space between extensor carpi radialis longus and brevis and branchioradialis on lateral side and extensor digitorum communis muscle on ulnar side. Supinator muscle being exposed was reflected subperiosteally proximally while protecting the deep branch of radial nerve thus exposing the fracture site.

Periosteum was stripped sparingly and all soft tissue attachments to communited fragments were preserved. Clotted blood or fibrous tissue was cleared away from fracture fragments edges and medullary canal. With the help of bone holding forcep the fracture was reduced by carefully matching the interdigitations.

Ulna

Ulna was exposed by posterior subcutaneous approach. In this approach a 10cm longitudinal incision was made over the sub-

cutaneous posterior border of ulna centered over the underlying fracture. Interval between flexor and extensor carpi ulnaris was identified. Fracture site was exposed with minimum periosteal stripping. It was cleared of clotted blood and fibrous tissue and reduced.

After trial reduction of both bones of forearm, either of the internal fixation devices were used.

Surgical Technique For Talwalkar's square nailing

Selection of nail :

Diameter of nail : This was assessed by measuring the narrowest diameter of medullary canal by anteroposterior radiological views of forearm.

Length of Nail : It was measured approximately preoperatively from tip of olecrenon to with in 2 cm of the ulnar styloid from the radiograph which was confirmed peroperatively. Similarly for radius, it was from radial styloid process to with in 1.3 cm of the radial head in the radiograph which was confirmed peroperatively.

Fixation of the bone which was less communited and easier was done first. Usually ulna was exposed and fracture was reduced with the help of mannual traction and manipulation with bone clamps, carefully matching the interdigitations, taking special care to maintain the rotatory alignment.

Steps of Nail Fixation in Ulna :

Proximal fragment was delivered through the wound. The canal

was reamed till the tip of reamer was felt beneath the skin at tip of olecrenon after testing the ulnar nail for fitting in medullary cavity.

Distal fragment was also reamed and length of nail measured with the help of guide wire in proximal and distal fragments respectively. Nail driver being applied on the tip of nail, the nail was pushed retrograde into canal of proximal fragment so that its proximal end protruded from the tip of olecrenon.

The fracture was carefully reduced, held with the bone holding forceps and the nail was driven through the distal fragment till three or four threads of proximal tip of nail remained outside the surface of olecrenon tip.

Steps of Nail Fixation in Radius :

Proximal and distal fragments were delivered and reamed in similar manner after measuring the fitting of radial nail in medullary canal, the length being measured in similar manner as above.

Nail was introduced in an antegrade manner. Portal tract for radial nail was made with help of small curved bone awl just above the tip of radial styloid between tendons of extensor carpi radials longus and extensor carpi radials brevis. Proper size radial nail was introduced through the portal, keeping the bevelled edge towards opposite cortex, the fracture being reduced and held with bone holding forcep. The nail was driven through fracture site into proximal fragment. Autogenous iliac bone grafts were applied if required.

Surgical Technique for DCP Plate Fixation

Radius

Fracture site being exposed and perfectly reduced plate was applied across fracture site and held with A.O. bone clamps. At least six hole plate was used so that at least five cortex purchase would be made on either side of the fracture. More communited or oblique fractures were fixed with longer seven or eight hole plates. Plate was applied on dorsal surface in proximal half and volar surface in distal half. In order to accomodate radial and dorsal bows, the plate was contoured with plate bending foreceps. With the neutral drill guide and 2.5 mm drill bit the plate hole nearest to the fracture site (at least from 1 cm from the fracture site), a hole was drilled.

Depth guage was used to ensure the screw length and 3.5 mm bone tap was used for tapping the screw hole. With hexgonal 3.5 mm screw driver, the screw of appropriate length was inserted but not seated completely. Next, the plate hole on other side of fracture nearest to fracture site was drilled, using eccentric drill guide with arrow of guide pointing towards fracture site. After measuring and tapping, screw was inserted. Now both the screws were tightened and seated completely. Rest of the screws were inserted using neutral drill guide. If the fracture was oblique screw were inserted obliquely after overdrilling the proximal cortex to give lag screw effect.

Eccentric screw in oblique fractures was inserted on the side

where fracture line made acute angle with the plate surface so that the fragments impacted beneath the plate surface rather than sliding over the fragment and disimpacting.

Ulna

Similarly plate was fixed on ulna on anterior or posterior aspect according to ease and the side of communition.

Closure

After fixing the fractured bones with either of the two devices, the muscles allowed to fall into place, suction drain tube was put, deep fascia sutured loosely, and then skin was sutured. C& D was done and A/E POP slab was applied.

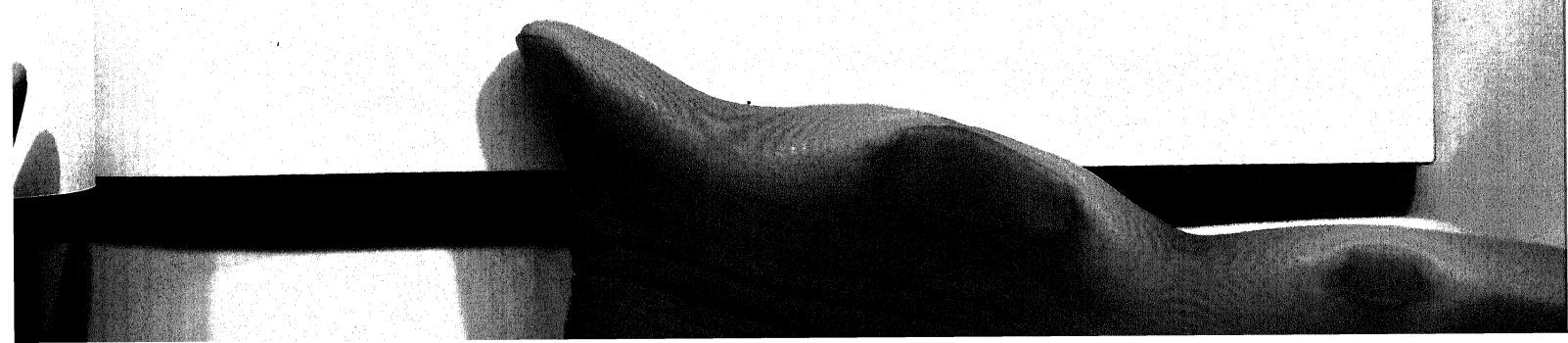
Post Operative Regimen

Prophylactic antibiotics were given for 7 days or more depending on condition of opreative wound. Active exercise of fingers and shoulder were started post operatively. Sutures were removed on 7th to 12th day.

Follow up : Patient was discharged if the operative wound was healthy and no other post operative complication was there to be managed. Plaster cast immobilization was continued for at least 3 weeks or more according to rigidity of fixation.

Patients were called for follow up at 3,6,12 and 20 weeks for clinical and radiological evaluation.

All relavent data were filled and tabulated so as to reach final



results :

1. Swelling of part.
2. Condition surgical wound.
3. Neurovascular status.
4. Type and duration of immobilization.
5. Functional status i.e. movements at various adjoining joints.
6. Radiological evidence of fracture union.
7. Return to employment.

Anderson (1975) criteria for union were *modified* and applied as under :-

1. Fracture healing in less than 4 months was considered as - *Normal union.*
2. Fracture healing requiring more than 4 months, upto 6 months, but no additional operative procedure was considered a- *Delayed union.*
3. Those which failed to unite even after 6 months and required another operative procedure, like bone grafting, were considered as - *Non union.*

Anderson et al (1973) creteria for rating functional results were applied :

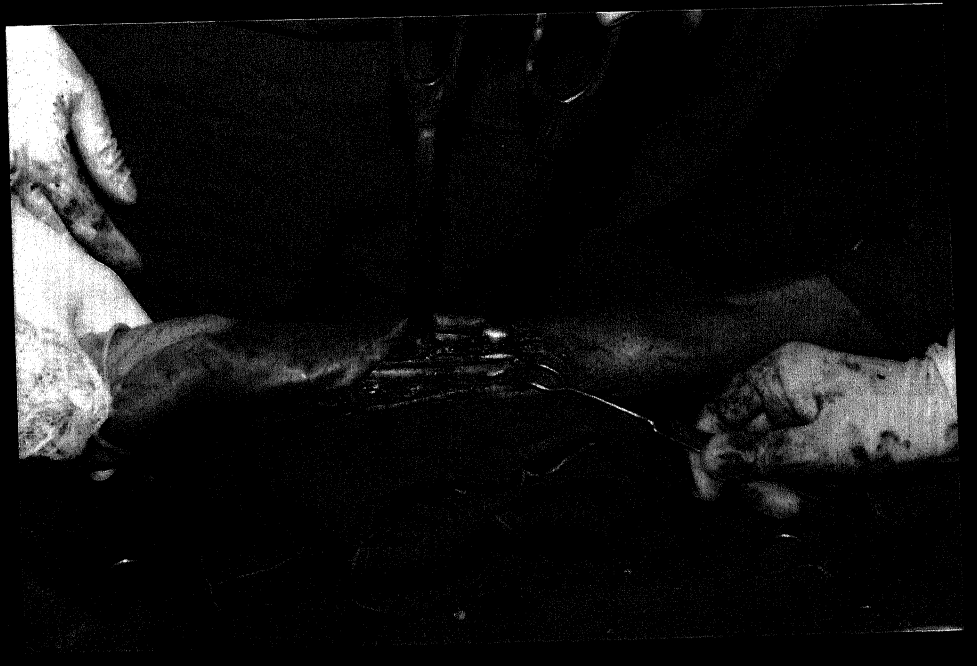
Excellent	Union of fractures with Normal (100%) rotational arc of supination and pronation of forearm and Normal (100%) flexion and extension range present at wrist & elbow.
Good	Union of fracture with >80% of rotational arc of supination and pronation of forearm and >90% of flexion and extension range present at wrist and elbow.
Acceptable	Union of fracture with >60% of rotational arc present and >80% of flexion and extension range present at wrist and elbow.
Poor	Non union and or less than 60% rotational arc and <80% of the forearm extension range present at wrist and elbow.

Photograph showing instruments and implants for DCP fixation of forearm fractures.

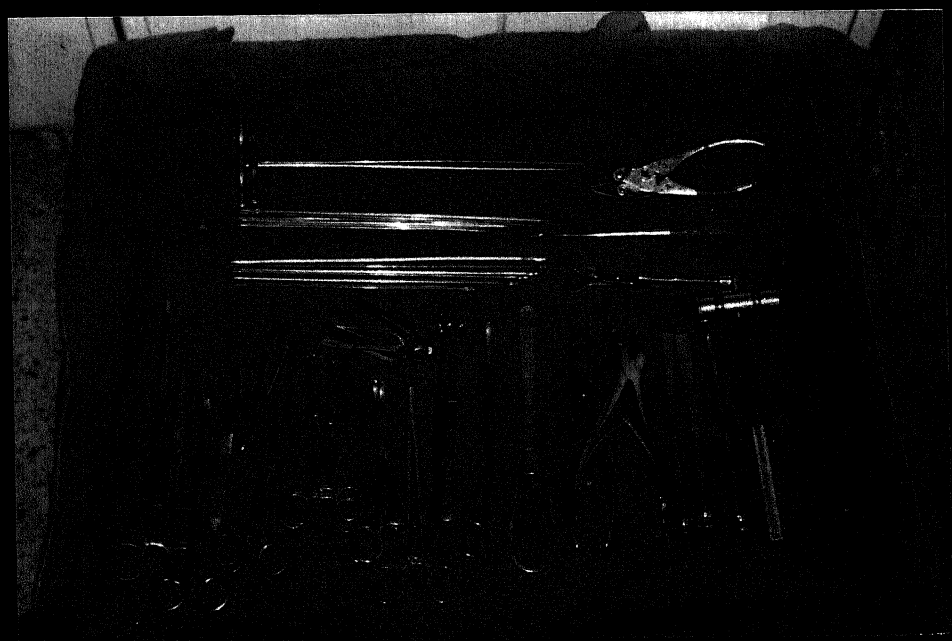
Fracture site at ulna being exposed by Posterior subcutaneous approach.

Peroperative photograph showing excellent reduction of fractured fragments and good position of implant.

Radius fracture site being exposed by Anterior Henry's approach

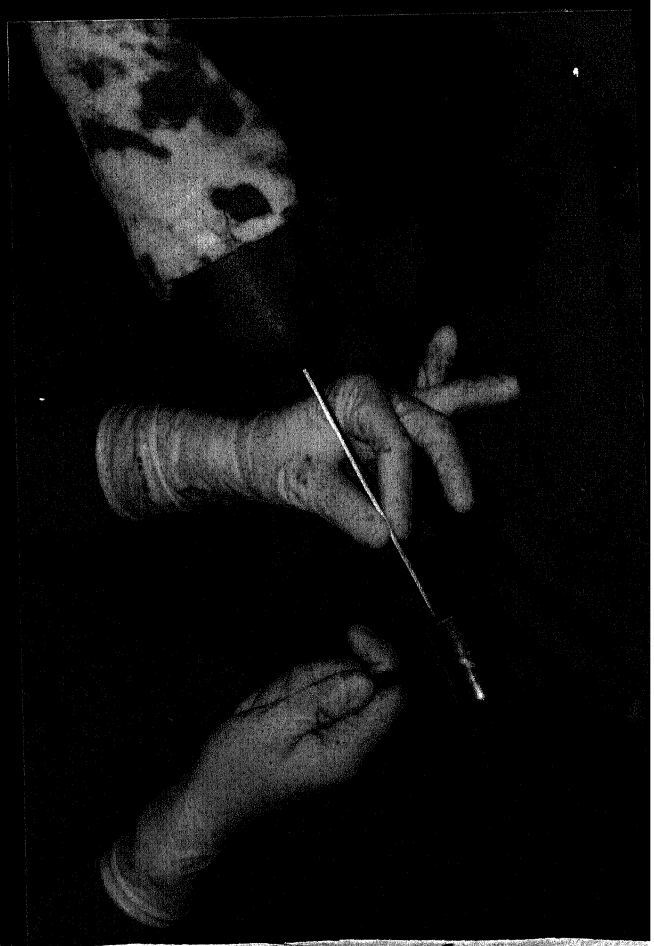


Per operative photograph showing excellent reduction of fractured fragments and good position of implant.



Photograph showing instruments and implants for square nail fixation

Fracture site at ulna being exposed by Posterior subcutaneous approach.



Ulnar square nail being post into the marraw canal after open reduction of fractured fragments

Excellent reduction being achieved at ulnar fracture site.

Radius fracture being exposed by Anterior Henry's approach.

Portal being made for introduction of Radial square nail.

Radial square nail being pushed halfway intothe marrow canal of the radius

Appearance of forearm immediatly after closure of both the surgical wounds (slight swelling of the forearm subsided on the second post operative day).

OBSERVATIONS

OBSERVATIONS

The present study consists of 18 patients with fractures of both bones of forearm. Out of these, 13 patients were treated by open reduction and internal fixation with Talwalkar's square nails for radius and ulna, and, the rest 5 cases were treated by open reduction and internal fixation with Dynamic compression plates (DCP) and 3.5mm cortical screws. Those patients treated by open reduction and square nail fixation were designated as Group I and those treated by open reduction and DCP fixation were designated as Group II. Important facts and relevant observation details were collected, and necessary calculation were done. This data was arranged in a tabulated form, and is being presented as follows :

Age and Sex incidence

Out of the total of 18 cases majority of patients were males, 15 (83.3%), and females were only 3 (16.6%). Sex distribution was quite similar in both group of patients with 84.6% males in Group I and 80% males in Group II.

The youngest of the patients was a 17 years old boy, and the oldest one was 80 years old elderly male patient. But most of the pateints were in age group between 20 years and 40 years. Age distribution was quite similar in both Group I and II patients with maximum number of patients, 69.2% and 60% respectively in 20-40 year age group. Average age, overall, of 18 patients came out to be 36.5 years, and that of Group

I 35.8 years and Group II 38.4 years. Thus, the average age was not significantly different in both group of patients.

Details of age and sex distribution are shown in following tables :

TABLE - I

Age distribution of patients

Age (years)	Group I		Group II		Overall	
	No. of cases	%	No. of cases	%	No. of cases	%
10-20	1	7.6	--	--	1	5.5
20-40	9	69.2	3	60	12	66.6
40-60	2	15.4	1	20	3	16.6
60-80	1	7.6	1	20	2	11.0
Total	13	100	5	100	18	100

Average age = Overall - 36.5 years

Group I - 35.8 years

Group II - 38.4 years

TABLE - II

Sex distribution of patients

Sex	Group I		Group II		Overall	
	No. of cases	%	No. of cases	%	No. of cases	%
Male	11	84.6	4	80	15	83.3
Female	2	15.4	1	20	3	16.6
Total	13	100	5	100	18	100

Mode of injury

Out of total of 18 cases, road traffic accidents alone accounted for 8 (44.4%) cases. Direct hit by lathi and wooden log accounted for 4(22.2%) cases. Fractures occured due to fall in 4 (22.2) cases. Out of these, 4 cases, 2 cases were young adults who fell from height, one was an elderly male who slipped on floor and fell on outstreched hand, and the fourth one was a young adult who slipped on road with heavy loads in both hands. Industrial accident accounted for 1 (5.5%) case. 1 (5.5%) patient got his forearm refractured through six months old healed fracture of forearm while lifting heavy weights.

TABLE - III

Mode of injury

Mode of injury	Cases	Percentage
Road Traffic accident	8	44.4
Direct hit	4	22.2
Injury due to fall	4	22.2
Industrial accident	1	5.5
Heavy load lifting	1	5.5
Total	18	100

Occupation of patients

Out of 18 cases maximum 4 (22.2%) were daily wage labourers. Amongst the rest of patients 2 (11%) were farmers, 2 (11%) were housewives, 2 (11%) were elderly dependents, 2 (11%) were teachers, 2(11%) were government employes, 2 (11%) were private servants, 1 (5.5%) person was an industrial worker, and one (5.5%) patient was a student.

TABLE - IV

Ocuupation of patients

Occupation	No. of cases	Percentage (%)
Daily wage labourer	4	22.2
Farmer	2	11.00
Housewife	2	11.00
Elderly dependent	2	11.00
Teacher	2	11.00
Government employee	2	11.00
Private servant Chauffer, domestic help)	2	11.00
Buisnessman	--	--
Industrial worker	1	5.5
Student	1	5.5
Total	18	100

Side of Limb

Out of total of 18 cases, 9 (50%) cases had fractures of right

forearm and 9(50%) cases had fractures of left forearm. Details are shown in Table no V.

TABLE - V

Side of limb

Side of Limb	No. of cases	Percentage
Left	9	50.00
Right	9	50.00
Total	18	100

Site of fracture

Out of total of 18 cases maximum 14 (77.7%) cases had fractures through middle 3rd of radius and ulna, 2 (11%)cases had fracture through upper 3rd and 2 (11%) cases had fracture through lower 3rd of both bones of forearm. Both radius and ulna got fractured through same levels whether it was upper 3rd or middle 3rd or lower 3rd level of forearm. In Group I most of the cases, 9 (69.2%), had fractures through middle 3rd, 2 (15.4%) cases through upper 3rd and 2 (15.4%) cases through lower 3rd.

In Group II all of the cases 5 (100%) had fractures through mid 3rd of forearm.

TABLE - VI

Site of fracture

Site of fracture	Group I		Group II		Overall	
	No. of cases	%	No. of cases	%	No. of cases	%
Upper 3rd	2	15.4	--	--	2	11.1
Middle 3rd	9	69.2	5	100	14	77.7
Lower 3rd	2	15.4	--	--	2	11.1
Total	13	100	5	100	18	100

Type of fracture

In our series of cases, fractures of ulna were transverse in 13 (72.2%) cases, spiral in 2 (11.1%) cases, comminuted in 1 (5.5%) case, segmental in 2 (11.1%) cases, and no oblique fracture of ulna was recorded. As regarding fractures of radius, transverse pattern of fracture was noted in 10 (55.5%) cases, oblique in 1 (5.5%) cases, spiral in 4 (22.2%) cases, comminuted in 3 (16.6%) cases and no segmental pattern of fracture was recorded. Thus, it was noted that transverse pattern of fracture was more common in fractures of both radius and ulna.

When pattern of fracture amongst combined radial and ulnar

fractures of Group I and Group II were compared, it was noted that maximum number of fractures 14 (53.9%) in Group I were transverse, 6 (23%) were spiral, 3 (11.5%) were comminuted and rest were oblique and segmental wheras in Group II 9(90%) fractures were transverse and 1 (10%) were comminuted.

Details are shown in table no. VII

TABLE - VII

Pattern of fracture

Pattern of fracture	Ulna	%	Radius	%	Overall	%
Transverse	13	72.2	10	55.5	23	63.8
Oblique	--	--	1	5.5	1	2.7
Spiral	2	11.1	2	22.2	6	16.6
Comminuted	1	5.5	3	16.6	4	11.1
Segmental	2	11.1	--	--	2	5.5
Total	18	100	18	100	36	100

Pattern of fracture	Group I		Group II	
	No. of frac. (Radius+Ulna)	%	No of frac. (Radius+Ulna)	%
Transverse	14	53.9	9	90.0
Oblique	1	3.9	--	--
Spiral	6	23.0	--	--
Comminuted	3	11.5	1	10.0
Segmental	2	7.7	--	--
Total	26	100	10	100

Nature of injury

In this series of cases, maximum 14 (77.7%) cases noted were simple and 4 (22.2%) cases were compound in nature.

TABLE - VIII

Nature of injury

Nature of injury	Group I		Group II		Overall	
	No. of cases	%	No. of cases	%	No. of cases	%
Simple	10	76.9	4	80.0	14	77.7
Compound	3	23.0	1	20.0	4	22.2
Total	13	100	5	100	18	100

Associated injuries

Most of the patients 13 (72.2%) had no other associated injuries. 3 (16.6%) cases had fractures of other bones and 2 (11.1%) cases had head and facial injuries. No associated neurovascular injuries were noted. The details are tabulated as follows :

TABLE - IX

Associated injuries

Associated injuries	No. of cases	Percentage
Fractures of other bones	3	16.6
Head and facial injury	2	11.1
Neurovascular injury	--	----
No associated injury	13	72.2
Total	18	100

Interval between injury and operation

In our series most of the patients 11(61.1%) were operated early i.e. with in 0-2 weeks of injury. 5(27.7%) cases were operated with in 2-8 weeks of injury and 2(11.1%) were operated after 8 weeks of injury.

TABLE - X

Interval between injury and operation

Duration (in weeks)	Group I		Group II		Overall	
	No. of cases	%	No. of cases	%	No. of cases	Overall
0-2	7	53.8	4	80.0	11	61.1
2-8	4	30.8	1	20.0	5	27.7
>8	2	15.4	--	--	2	11.1
Total	13	100	5	100	18	100

Operative intervention done

In our series of fractures of both bones of forearm intramedullary nail fixation was done in 13(72.2%) cases which were taken as Group I. 5(27.7%) cases were fixed by Dynamic compression plates (DCP) and 3.5mm cortical screws and were taken as Group II.

TABLE - XI

Procedure done	No. of cases	%
Intramedullary square nail fixation (Group I)	13	72.2
D.C.P. fixation (Group II)	5	27.7
Total	18	100

Operation time and Bone grafting

In our series of cases average operative time taken in intramedullary nail fixation was 1 hrs. 40min and that in D.C.P. fixation was 1hrs. 55min.

Bone grafting was done in Group I in 3(23%) cases and in Group II it was done in 2(40%) cases, so out of total 18 cases bone grafting was done in 5(27.7%) cases which had comminution or were old fractures.

TABLE XII

Bone grafting

Bone grafting	Gp I	%	Gp II	%	Overall	%
Done	3	23.0	2	40.0	5	27.7
Not done	10	77.0	3	60.0	13	72.2
Total	13	100	5	100	18	100

Post operative hospital stay : Injectable antibiotics were continued for around 5 or 6 days post operatively which were replaced

by oral antibiotics for around 10 more days for most of the patients. Sutures were removed in most of the patients by 7th or 8th day post operatively, after which with in a day or two patients were discharged. The average hospital stay of patients, overall, was 11 days.

Duration of post operative POP splint immobilization

In our series of cases, post operative A/E POP slab splintage in mid prone forearm position was given to all patients till sutures were removed. Later on the immobilization was continued as POP cast for varying periods from 3 weeks to 5 months (20 weeks). A variety of factors determined the time of removal of POP cast :

(a) Adequacy of reduction of fractured fragments and position of internal fixation device at the time of operation.

(b) Apposition of fragments and position of internal fixation device noted in the radiographs taken at every 3 weeks interval in follow up.

(c) Appearance and consolidation by bridging callus seen in successive follow up radiographs.

In Group I patients, the casts were removed in maximum number no. of cases, 6(46.1%), between 9-12 weeks post operatively. Minimum time taken for removal of cast was 6 weeks, in this group, and that was for only 1 (7.7%) case, who was a young boy of 17 years with simple fracture of both bones, at mid

3rd level.Maximum time taken was 20 weeks and that was also for only one (7.7%) patient of this group, who had compound segmental fracture of ulna. 2(15.4%) cases got their casts removed between 12-16 weeks.

During the study of Group II cases it was found that casts were removed in maximum number of cases, 2 (40%), between 3-6 weeks. Minimum time taken was 3 weeks for removal of cast in 1(20%) patient. 1(20%) pateint of this series required immobilization for 12 weeks. The fracture was comminuted and there was post operative superficial infection in surgical wound in this case.

TABLE -XIII

Duration of post operative immobilization

Duration of (weeks) immobilization	Group I	%	Group II	%
0-3	--	--	1	20.0
3-6	1	7.7	2	40.0
6-9	2	15.4	1	20.0
9-12	6	46.2	1	20.0
12-16	3	23.0	--	--
>16	1	7.7	--	--
Total	13	100	5	100

Average time of post operative POP cast immobilization in :

(a) Intramedullary square nail fixation (Group I)

-12 weeks 3 days

(b) D.C.P. fixation (Group II) - 7 weeks 2 days

The overall average time in 18 cases of both groups was 11 weeks.

Post operative complications

In our series of patients, in the Group I, superficial infection occured in 2(15.4%) cases, deep infection which led to osteomyelitis occured in 1 (7.7%) patient. Tourniquet palsy, neurovascular injury and olecrenon bursitis occured in 1(7.7%) case each respectively. One case of implant failure was recorded. This patient suffered fatigue breakage of ulnar nail and refarcture of ulna, six months after both bone sqaure nail fixation. This occured because patient had started using the limb for heavy work before complete fracture consolidation. Rest 6(46.1%) cases did not have any complication.

TABLE -XIV

Post operative complications

Complications	Group I	%	Group II	%
Superficial infection	2	15.4	1	20.0
Deep infection (Osteomyelitis)	1	7.7	--	----
Tourniquet palsy	1	7.7	--	----
Neurovascular injury	1	7.7	1	20.0
Olecrenon bursitis	1	7.7	--	----
Implant failure	1	7.7	--	----
No complication	6	46.1	3	60.0
Total	13	100	5	100

Clinical follow up

In our series of cases of Group I, 11 cases had swelling in hand and fingers in immediate post operative period. In 6 cases it subsided with in 3-4 days. 5 patients continued to have swelling upto 3 weeks. In one patient with Grade III compound injury with comminuted fracture the swelling continued till 6 weeks. Neurovascular injury in form of posterior interosseous nerve

neuropraxia and tourniquet palsy occured in 1 case each which recovered at 9 and 12 weeks respectively. Superficial infection occured in 2 cases which recovered, by 3rd weeks, in one case and 6th weeks, in the other case. Deep infection occured in one patient with grade III compound comminuted segmental fracture which led to chronic osteomyelitis of both bones in operated forearm.

TABLE - XV

Clinical follow up - Group I

No. of weeks	0	3	6	9	12	16
Swelling	11	5	1	--	--	--
Neurovascular injury	1	1	1	1	--	--
Tourniquet palsy	1	1	1	1	1	--
Superficial infection of surgical wound	--	2	1	--	--	--
Deep infection (Osteomylitis)	--	1	1	1	1	1

Group II patients,. immediate post operative swelling was seen in 4 cases which subsided with in few days in 3 of them and it continued upto 3 weeks in one case. There was one case of posterior interosseous nerve neuropraxia which recovered by 3rd weeks. Superficial infection of surgical wound was seen

in 2 cases which recovered by 9th weeks.

TABLE - XVI

Clinical follow up - Group II

No. of weeks	0	3	6	9	12	16
Swelling	4	1	--	--	--	--
Neurovascular injury (Post interosseous nerve neuropraxia)	1	1	--	--	--	--
Tourniquet palsy	--	--	--	--	--	--
Superficial infection of surgical wound	--	2	2	--	--	--
Deep infection (Osteomyelitis)	--	--	--	--	--	--

Radiological follow up

Apposition of fracture fragments and position of implant

In our series of patients in Group I there was good (>70%) apposition of fractured fragments in 9(69.2%) cases, most of which were transverse fractures through mid 3rd of shafts of radius and ulna. Satisfactory (>50%) apposition was noted in 3(23%) cases. Poor (<50%) apposition was observed in 1 (7.6%) patient with comminuted fracture of radius at the junction of upper and middle 3rd.

In Group II patients, good apposition of fractures fragments was noted in 4(80%) cases. 1 (20%) case of comminuted fracture of radius at junction of middle and upper 3rd had satisfactory (>50%) apposition. There was no case with poor (<50%) apposition.

The distribution of status of implant was identical to the distribution of fracture fragment apposition as without proper fracture reduction, the proper position and fixation of implant could not be achieved. Moreover, both the status of fragment apposition and implant position remained unchanged on successive radiological examinations in both groups of patients.

TABLE - XVII

Fracture apposition and position of implant

Fracture apposition & position of implant	0	3	6	9	12	16	%
Group I							
Good	9	9	9	9	9	9	69.2
Satisfactory	3	3	3	3	3	3	23.0
Poor	1	1	1	1	1	1	76.0
Group II							
Good	4	4	4	4	4	4	80.0
Satisfactory	1	1	1	1	1	1	20.0
Poor	--	--	--	--	--	--	----

Amount of bridging callus and fracture union

In the fractures in Group II, which were fixed rigidly with D.C.P. fixation, very little external callus was observed. Fracture union in these cases was ascertained by appearance of bridging trabeculae across the fracture line. There was good amount of callus formation in the patients of Group II fixed by square nails. Anderson et al (1975) criteria for fracture union were modified and applied in our study.

Fracture union in less than 16 weeks (4months) was considered as normal union. Fracture union requiring more than 16 weeks (4months) upto 24 weeks (6months), but no additional operative procedure, was considered as *delayed union*. Fractures which failed to unite even after 24 weeks (6months), where fracture margins appeared smooth and sclerosed, and which required some additional operative procedure like bone grafting were considered as *non union*.

In Group I patients, first sign of any callus formation on radiograph appeared at around 6 weeks in maximum number 6(46%) of cases. The radiological fracture union took place in maximum number 5(38.5%) of patients at around 16 weeks. In most of the cases fracture of ulna united at an average of around 2 weeks earlier than fracture of radius. In 1(7.6%) 17 years old case, with simple transverse fracture through mid 3rd, callus appeared the earliest at 3 weeks and consolidated by 9 weeks in both bones of forearm. In 1(7.6%) patients who had com-

pound comminuted segmental fracture of ulna and compound comminuted fracture of radius it took 24 weeks for complete fracture union. 1(7.6%) patient with compound fracture Grade III of both bones developed osteomyelitis and infected non union of both bones of forearm.

In Group I patients first sign of any callus formation appeared in maximum number of cases, 3 (60%), at around 6 weeks post operatively. Fracture union took place in most of the patients 3 (60%) of Group II at around 9 weeks. Fracture union was delayed upto 20 weeks in 1(20%) patient who was a case of one year old non union of both bones of forearm.

According to our modified criteria there were 3 delayed union in Group I and 1 (7.6%) went into infected non union of both bones of forearm. There was 1 (20%) case of delayed union in Group II patients. According to original Anderson's criteria there was no delayed union in any case of both groups and there was one (7.6%) infected non union in Group I.

Note - *Original Anderson's (1975) criteria are :*

Union : *Fracture union with in six months.*

Delayed union : *Fracture union occuring after six months but not requiring any additional operative procedure.*

Non union : *Sclerosis and smoothening of fracture margins requiring some additional operative procedures like bone grafting.*

TABLE - XVIII

Amount of bridging callus

Amount of bridging	0	3	6.	9	12	16	20	24
Group I								
Minimal	--	1	6	3	3	--	--	--
	--	7.6%	46.%	23%	23%	--	--	--
Adequate	--	--	1	3	5	2	1	--
	--	--	7.6%	23%	38.5%	15.4%	7.6%	--
union	--	--	--	1	3	5	2*	1#
	--	--	--	7.6%	23%	38.5%	15.4%	7.6%
Group II								
Minimal	--	--	3	2	--	--	--	--
	--	--	60%	40%	--	--	--	--
Adequate	--	--	--	3	1	1	--	--
	--	--	--	60%	20%	20%	--	--
union	--	--	--	--	3	1	1*	--
	--	--	--	--	60%	20%	20%	--

* → Delayed union (within 4 months to 6 months acc. to our modified criteria)

\# → Infected non union

Note : According to original Anderson 1975 criteria there

is no case of delayed union in our study.

Final functional assesment

After the bony union had occured at the fracture site, in both bones of forearm, the patient was advised to undertake active mobilization exercises at wrist, forearm and elbow for about 15-20 days. The range of rotational arc of supination and pronation and flexion extension range at the wrist and elbow joint were measured.

In the patients of Group I, normal or 100% range of rotational arc of forearm was noted in 1(7.6%) case, 5(38.5%) patients had a good >80% range of rotational movements. 4(30.6%) cases had satisfactory >60% range of rotational movements of forearm.

2(40%) case of Group II were able to achieve their normal range of rotational arc of forearm. 1 (20%) case achieved good >80%, and 2(40%) case achieved satisfactory >60% range of rotation in forearm. None of the patient in this group had poor or <60% range of rotational arc of forearm.

The distribution of flexion and extension range at wrist and elbow in Group I was observed as Normal in 1(7.6%), >90% in 5(38.5%) . >80% in 4(30.6%) and <80% in 3(23%) cases. In Group II this was observed as Normal in 2(40%) cases, >90% in 1(20%) case and >80% in 2(40%) cases. None of the case in this group had <80% range.

TABLE - XIX

Range of rotational arc of forearm

Range of rotational arc of forearm (% of normal range)	Group I		Group II	
	No. of cases	%	No. of cases	%
Normal or 100%	1	7.6	2	40.0
>80	5	38.5	1	20.0
>60	4	30.6	2	40.0
<60	3	23.0	--	--
Total	13	100	5	100

TABLE - XX

Range of flexion and extension at wrist and elbow

Flexion extension range at wrist & elbow (% of normal range)	Group I		Group II	
	No. of cases	%	No. of cases	%
Normal or 100%	1	7.6	2	40.0
>90	5	38.5	1	20.0
>80	4	30.6	2	40.0
<80	3	23.0	--	--
Total	13	100	5	100

Overall assessment of fracture healing and functional results

The results of the operative treatment of fractures of both bones of forearm, in two groups, Group I and Group II, were graded in our study. The Anderson criteria were modified and applied for rating the results of operative treatment. The details of this criteria are as follows :

Excellent : Union of fracture with Normal (100%) rotational arc of supination and pronation of forearm and Normal (100%) range of flexion and extension movement at wrist and elbow.

Good : Union of fracture with >80% of rotational arc of supination and pronation and >90% of flexion and extension range of wrist and elbow joint.

Acceptable: Union of fracture with >60% of rotational arc and >70% of flexion and extension movements at wrist and elbow.

Poor : Non union or less than 60% of rotational arc of forearm and <80% of flexion extension range at adjoining joints.

Note : *Union - includes normal as well as delayed union. Anderson (1975) criteria for fracture union were modified and applied.*

According to above mentioned criteria in Group I, there was 1(7.7%) case with Excellent results, 5(38.5%) cases with Good

results 4(30.7%) cases with Acceptable results and 3(23%) cases with Poor results.

In Group II the results were better with, 2(40%) Excellent, 1(20%) Good, 2(40%) Acceptable results. There was no case with Poor results.

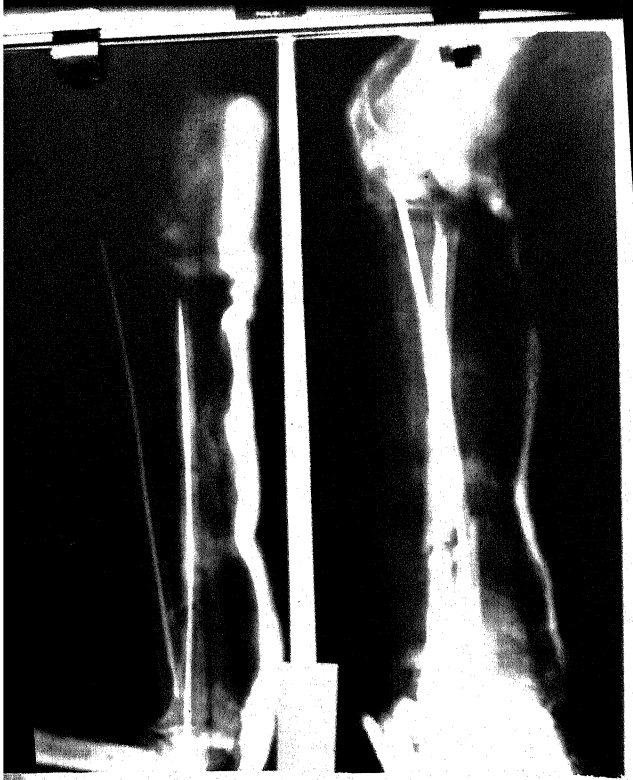
Removal of Implant

In one case with compound segmental fracture of shaft of ulna the ulnar nail was removed approximately 1 year after the date of operation. The fracture had completely united and the proximal protruded end of ulnar nail was causing olecrenon bursitis.

In other case, with compound fracture, where both bone forearm square nailing was done, osteomyelitis of both bones forearm developed, infected non union of both bone fracture occured, square nails of ulna and radius were removed and currettage of infected bone was done. Immobilization was continued as A/E POP cast. There was one more case in Group I where patient undertook heavy activity with limb, before the fracture could get consolidated and fatigue breakage of ulnar nail and refracture of ulna occured, 6 months after operation. The ulnar nail was replaced by a new nail, bone grafting was done and proper duration of immobilization was given after which the fracture again united.

No case of Group II required any removal of implant.

Case A -(Group-I)
Pre-operative Radiograph showing comminuted segmental fracture of ulna and spiral fracture of radius (This was a compound grade II injury).



Immediate post operative Radiograph depicting adequate fixation.

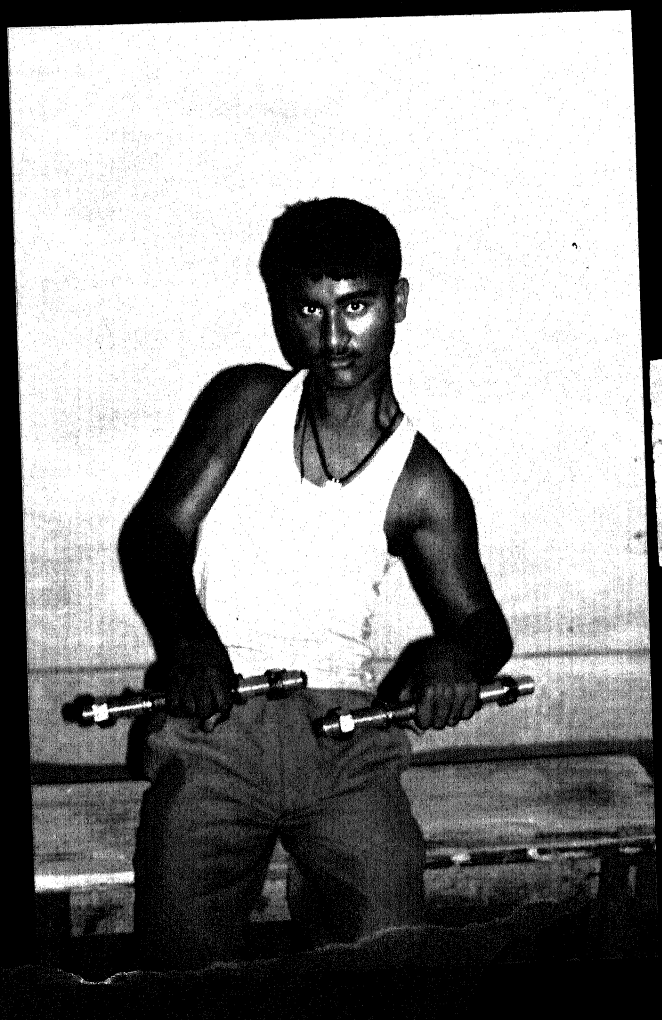
Follow-up Radiograph at 9 weeks showing minimal callus formation

Follow-up Radiograph at 12 weeks showing fracture callus in process of consolidation

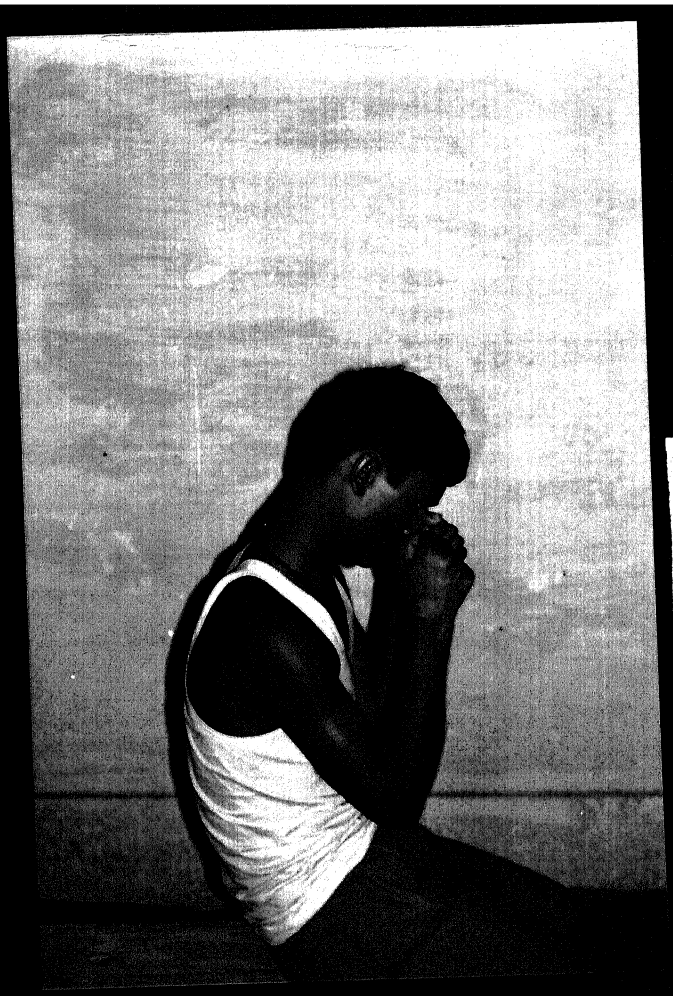
Follow-up Radiograph at 20 weeks showing complete fracture union with adequate consolidated fracture callus.

Follow-up Radiograph at 10 months after removal of ulnar square nail for relieving olecrenon bursitis.

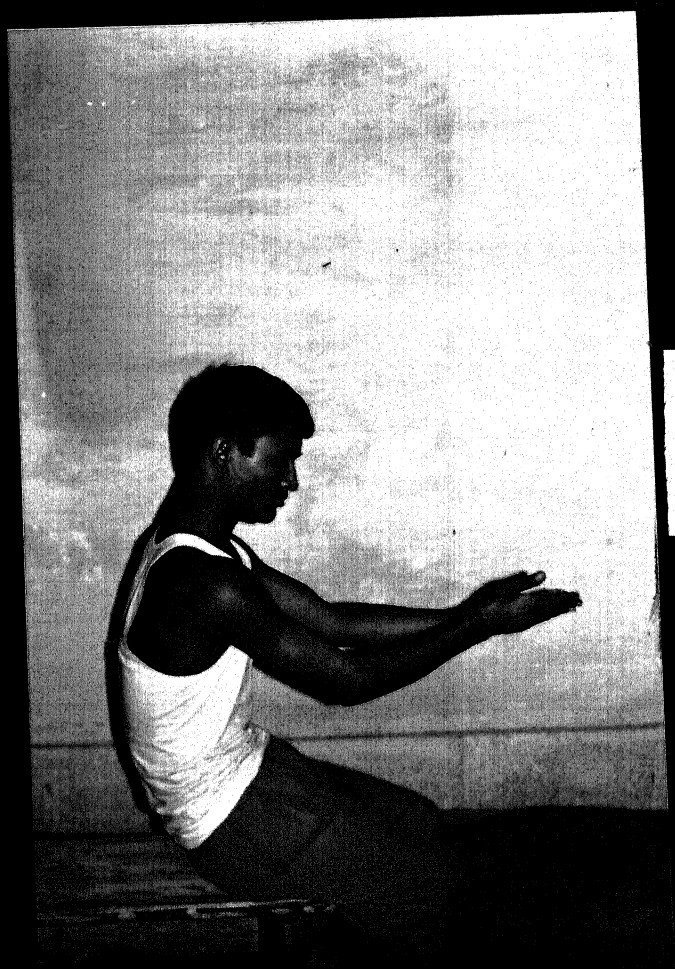
Case A (Group -I)
Clinical follow-up photograph at 24 weeks showing Normal range of supination in the operated Right forearm.



Follow-up photograph showing acceptable range of pronation in right forearm.

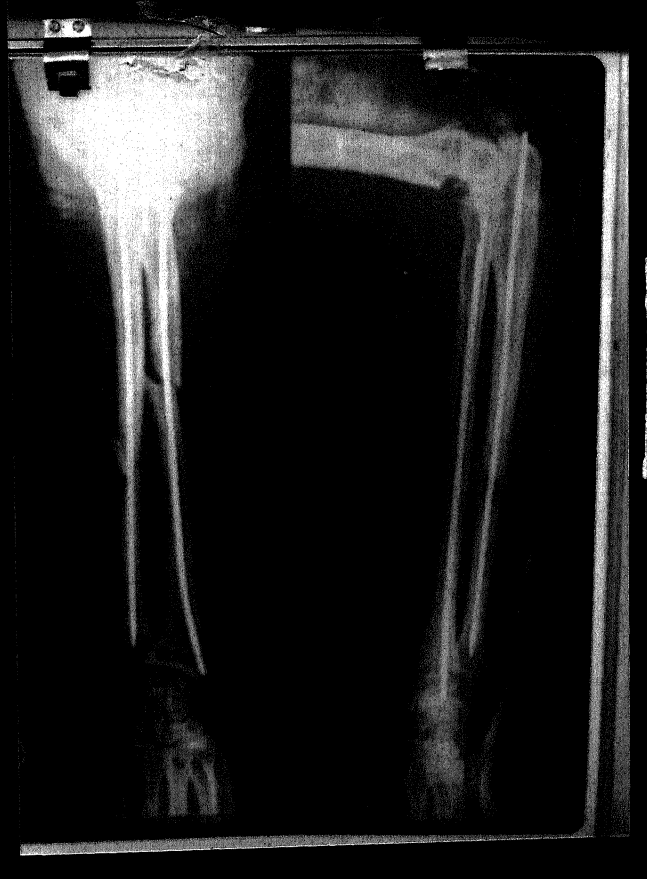


Follow-up photograph showing good range of flexion at elbow.



Follow-up photograph showing acceptable range of extension at elbow.

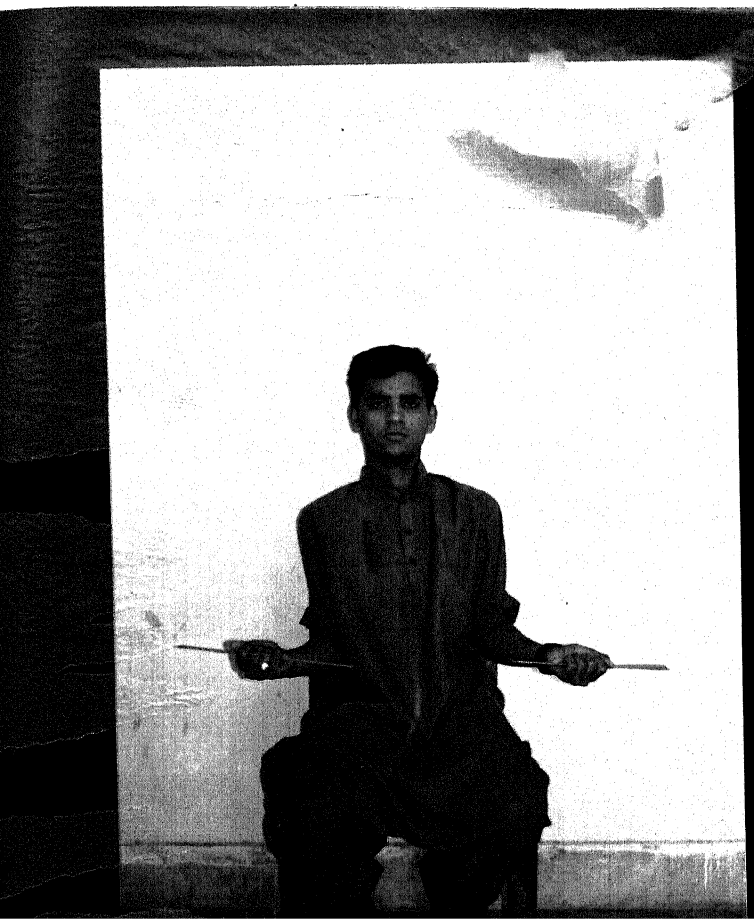
Case B (Group -I)
Pre-operative Radiograph showing spiral fractures of both bones with minimal comminution in the fracture of ulna.



Follow-up Radiograph at 3 weeks showing minimal callus formation.

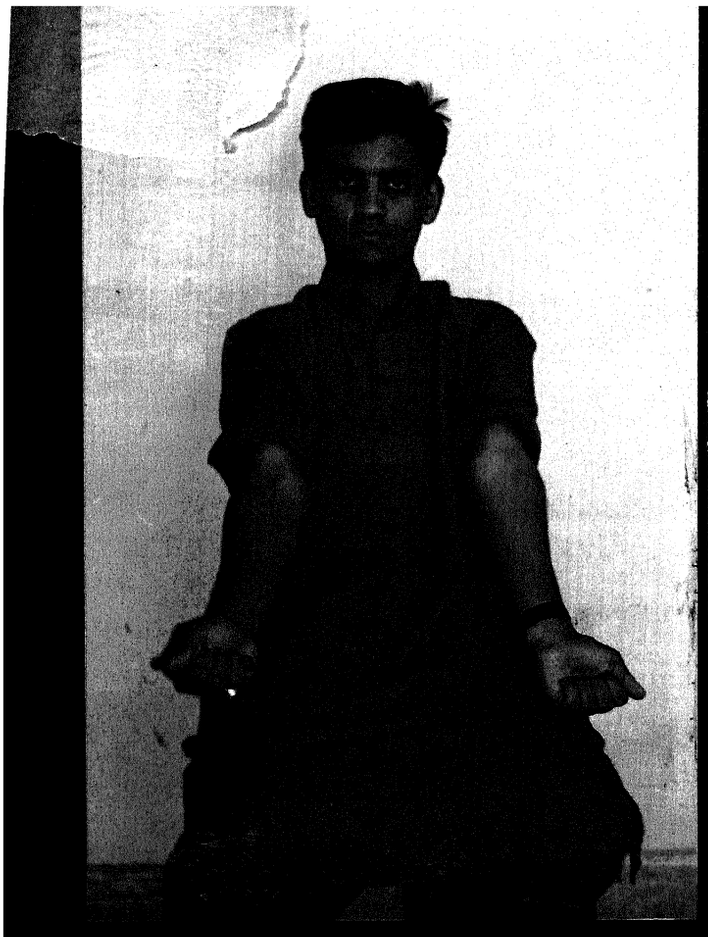
Follow-up Radiograph at 9 weeks showing complete fracture union with adequate consolidated fracture callus.

Follow-up Radiograph at 10 months showing complete maturation of fracture callus and the remodelling of bone.

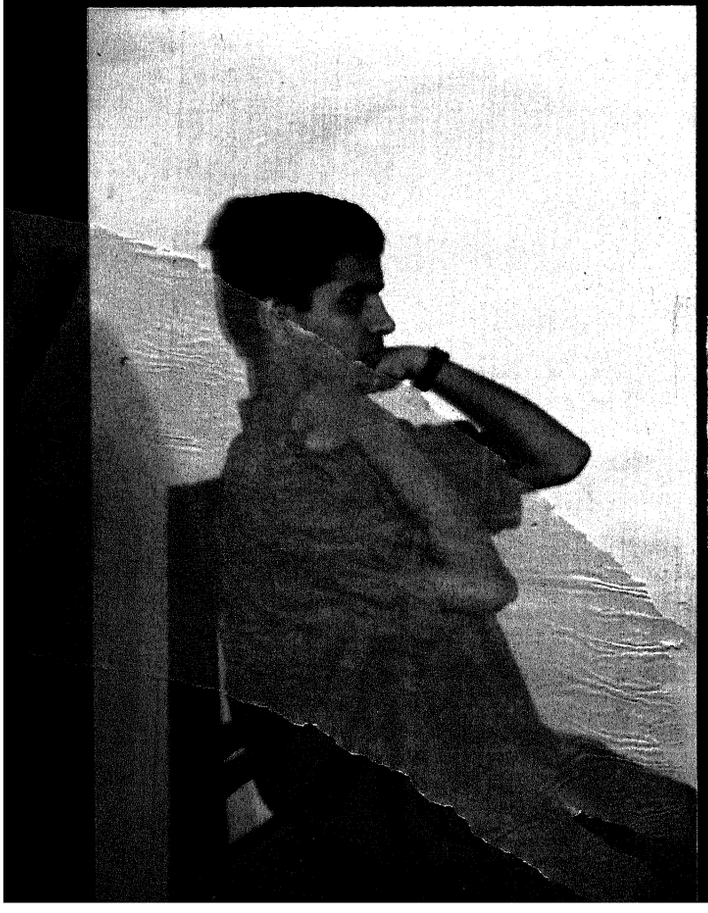


Case B (Group -I)
Clinical Follow-up photograph at 12 weeks showing Normal range of supination in the operated Right forearm.

Photograph showing Normal range of pronation in Right forearm.



Photograph showing Normal range of extension at Right elbow joint.

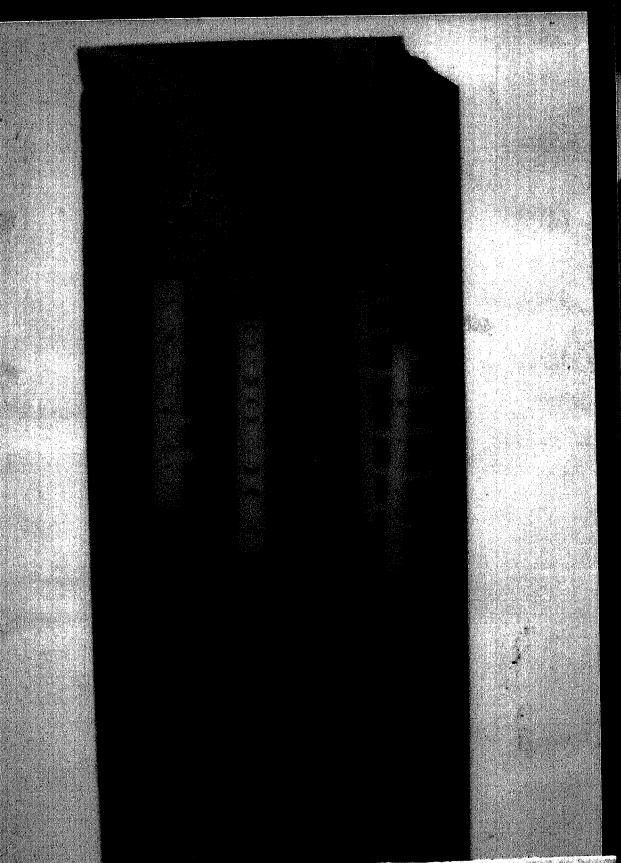


Photograph showing Normal range of flexion at Right elbow.

Photograph showing Normal range of dorsiflexion at Right wrist.

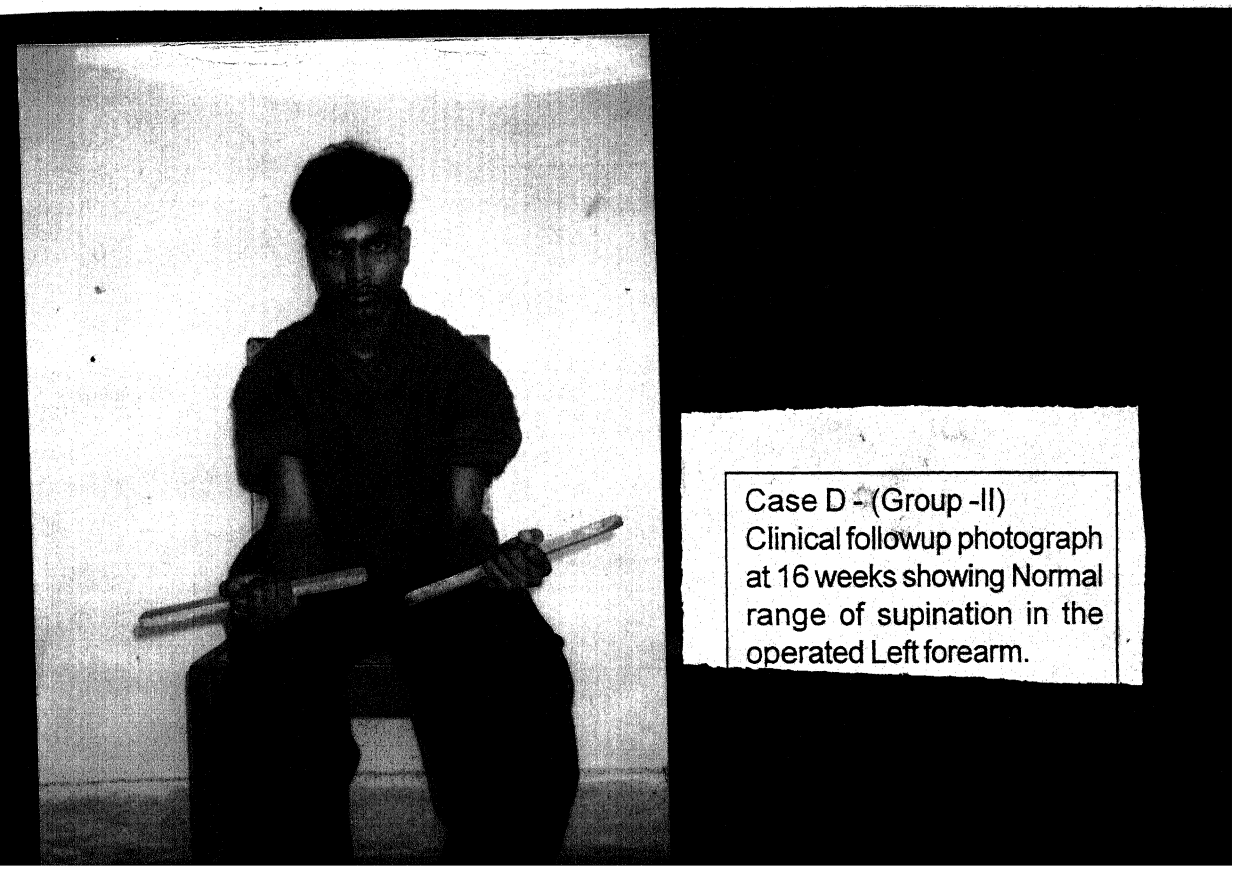
Photograph showing Normal range of palmar flexion at Right wrist.

Case D - (Group -II)
Preoperative Radiograph showing spiral fracture of both bones of forearm.



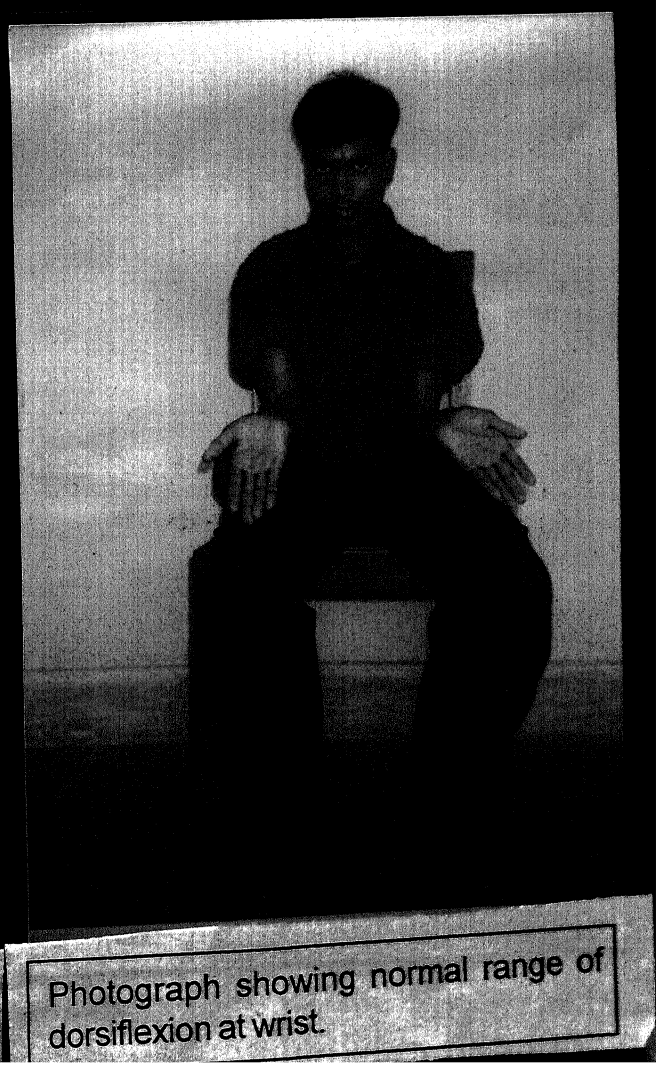
mmediate post operative Radiograph showing good reduction and adequate position of implant.

Follow-up Radiograph at 12 weeks showing complete fracture union



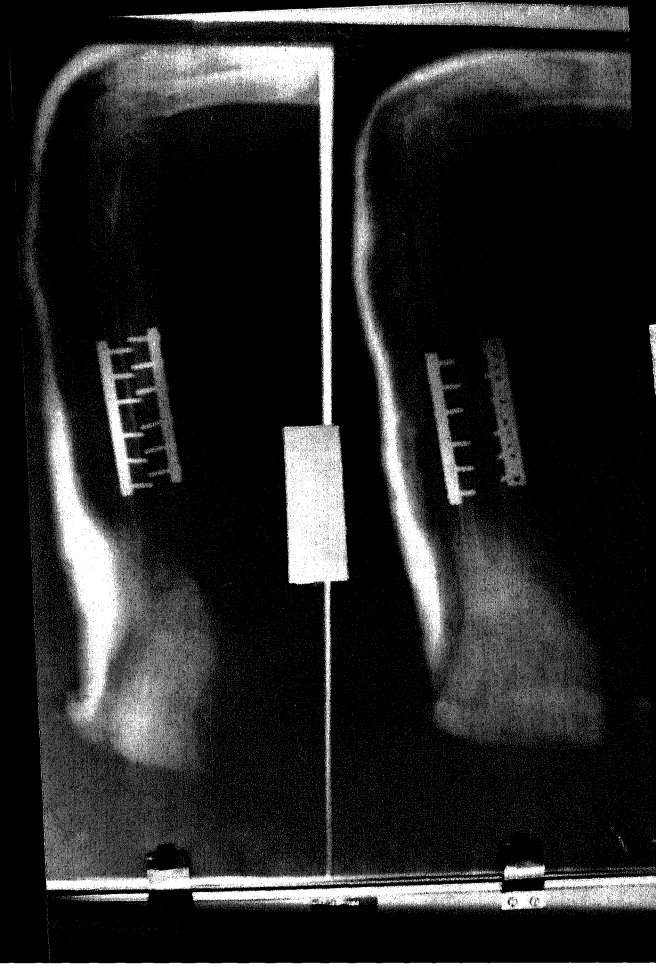
Case D - (Group -II)
Clinical followup photograph at 16 weeks showing Normal range of supination in the operated Left forearm.

hotograph showing good range of
ronation of forearm.

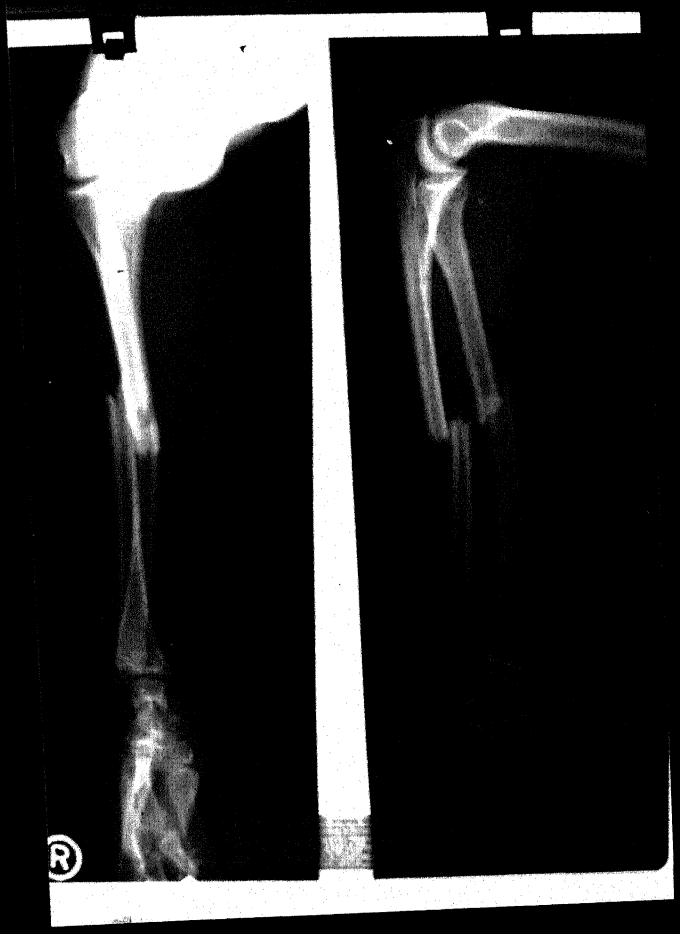


Photograph showing normal range of dorsiflexion at wrist.

Case E - (Group II)
Preoperative Radiograph showing transverse fracture of both bones of forearm.



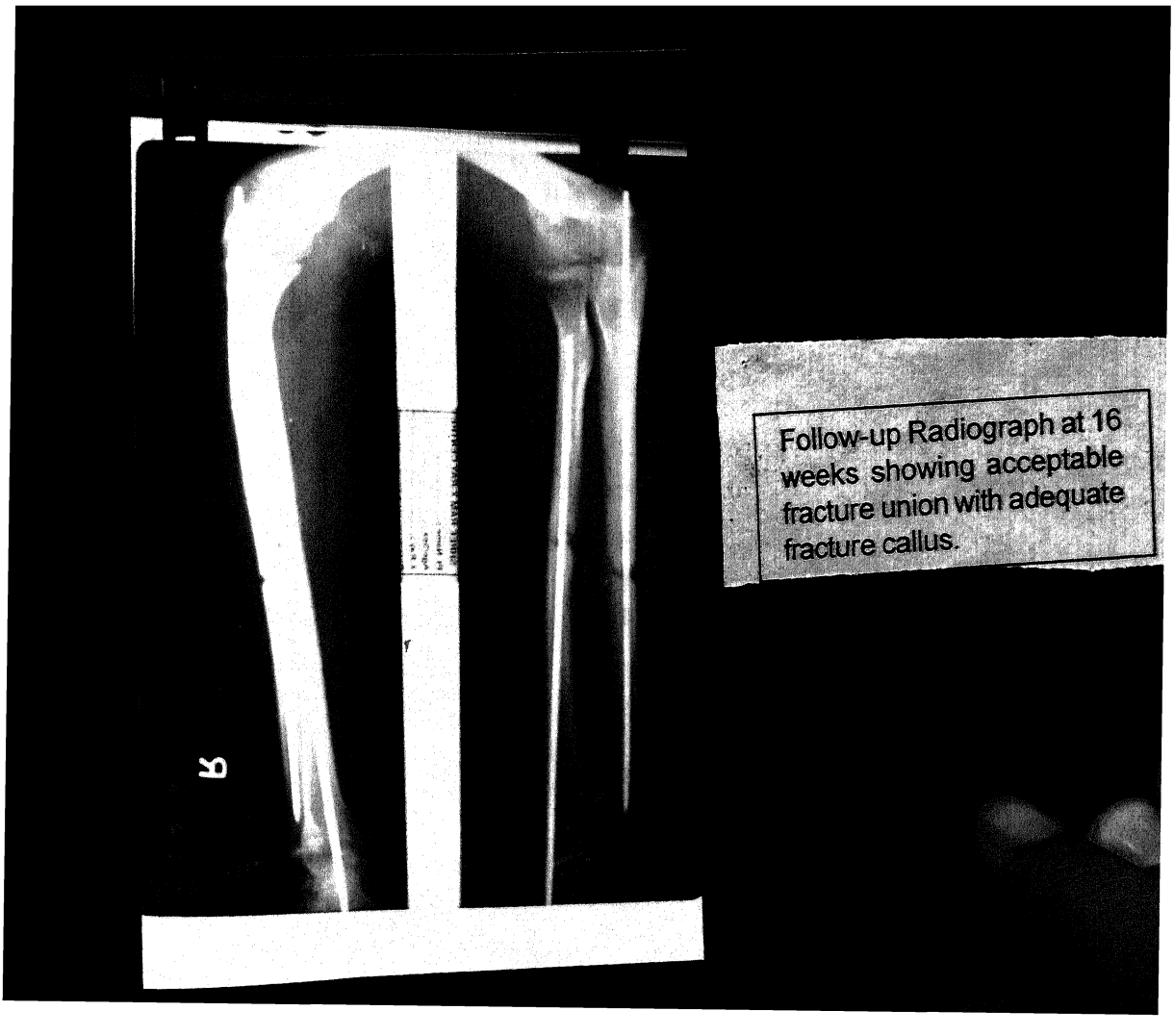
Immediate post-operative Radiograph showing adequate fracture reduction and good position of implant.



Case C (Goup -I)
Preoperative Radiograph showing spiral fracture of radius and transverse fracture of ulna.

Immediate post-operative Radiograph showing adequate fracture reduction and good position of implant.

Followup Radiograph at 9 weeks showing minimal callus



Follow-up Radiograph at 16 weeks showing acceptable fracture union with adequate fracture callus.

DISCUSSION

DISCUSSION

This study was conducted in the Department of Orthopaedics, M.L.B. Medical College on 18 cases of fracture of both bones of forearm, which were randomly selected and treated by two different modalities of internal fixation i.e. the intramedullary square nail and the Dynamic compression plate (DCP). Two groups were formed, Group I treated by square nail fixation and Group II treated by D.C.P. fixation. Patients were studied from the day of admission through the pre, intra and post op period, to the complete follow up till the patient achieved maximum possible functions of the injured limb. The data collected in this manner for the two group of cases was evaluated, analysed and compared with each other and with the previously done studies reported by various authors at different centres in the world.

The variable factors associated with patients in the two groups such as age, sex, mode of injury, site & type of fracture and nature of injury were compared so that results of operation could be evaluated and compared properly.

While evaluating *age distribution* in this series of patient, the overall age of patients came out to be 36.5 years. Average age of Group I was 35.8 years and that of Group II was quite similar i.e. 38.4 years. Overall more than 60% patients belonged to age group of 20-40 years, the young active adult age group, which is most prone to incidents of trauma.

The average age in our study was about 10 years less than that reported by different western authors. *Marek 1961* reported an average age of 43 years and *Burnwell and Charnley 1964* reported average age of 44.8 years in their series of cases. This discrepancy probably occured due to the fact that the average life expectancy in our country is quite less than that of western world.

These same socio- cultural differences explain the lower percentage of females amongst injured cases. 34% and 30% female patients were reported by Marek (1961) and Burnwell (1964) in their series of cases. Whereas the percentage of female patients in our series in Group I was 15.4% and Group II was 20%.

Considering the *mode of injury* in our series of cases, out of total of 18 cases, road traffic accidents alone accounted for 8, 44.4%, cases direct hit by stick or lathi 4, 22.2%, fall from height 22.2%, industrial accidents 1% and 1% due to other causes. This distribution was somewhat similar to the series of cases reported by Shah et al (1988) in which R.T.A. accounted for 5.3% cases, industrial injuries 14.7%, domestic injuries 16% and other causes 13.9%, which included fall from height or direct hit by stick.

Regarding the *occupation* of cases in our study, most of them, 33%, were daily wage laboures or poor farmers. The dominant upper limb was affected in 42.3% cases in Chapman series. But in our study, both side of limb appeared with equal frequency i.e. 50% each. In Group I, most of the cases, 69.2%,

had fractures through middle 3rd. In Group II, all 100% cases had fracture through middle 3rd of forearm.

In a study by Chapman et al, in a similar manner the middle 3rd of forearm was found to be most vulnerable portion of forearm to be fractured in any incidence of trauma.

While observing the *pattern of fracture* in our series of cases, it was found that in Group I maximum, 53.9%, of fractures were comminuted, 7.7% segmental and rest oblique. Whereas there was no case with oblique, spiral, or segmental fracture pattern in Group II. Here, in Group II, 90% of fractures were transverse and rest 10% were comminuted. In the study by Chapman, the proportion of various pattern of fracture was quite similar to our Group I patients except that comminuted fracture pattern was found in 53% of cases. This discrepancy could be explained by the poor quality of preoperative radiographs where small portion of comminution along fracture line could not be seen.

While evaluating the *nature of injury* in our series of cases it was found there were 76.9% cases with simple and 23% with compound injuries in Group I. This was quite similar to Group II where 80% cases had simple injury and 20% cases had compound injury. Out of total of 4(22%) cases of compound injury in our study, 2(11%) were Grade I with puncture wound and 2(11%) cases with Grade II and Grade III compound injuries respectively. This distribution pattern was quite similar to Anderson series where 88.6% fracture were simple

in nature. 40% cases had associated multiple injuries in Chapman's series of cases, while in our study this number was marginally less, with 27.8% cases having associated injuries.

The average *time interval between injury and operation* in Anderson's series was 10.6 days. In Chapman series 68.5% cases were operated with in two weeks after injury. In our series of cases, also, 53.8% cases of Group I, 80% cases of Group II, and overall 61.1% cases got operated with in two weeks after the date of injury,

Knight & Purvis 1949, Holdsworth 1949 and Smith 1956 stated that fractures of both bones of forearm are unsuitable for conservative treatment. Adler 1965, Chapman and Frankel 1973 and Sisk 1980 concluded that angulatory and rotatary, malunion and non-union occuring in these fractures treated by closed reduction and external immobilization resulted in marked functional impairment. Thus we set out in our study to compare the two modes of internal fixation.

Sisk 1980 studied the principles of intramedullary fixation, where he found intramedullary fixation better when the fractures occured through the narrow part of the medullary canal. Smith and Sage 1957, Sage (1959) Marek (1961) Cotler and associates (1971) in their studies concluded the favourable results of intramedullary nail fixation.

Whereas Dodge and Cady (1972) Anderson et al (1975) Grace and Eversmann (1980) Hadden (1983) supported fixation of

forearm bones with compression plates and found good results. Bagby (1957,1968) and Denham (1969) Allgower (1970) suggested dynamic compression plates.

In this present series of patients we have set out to evaluate various aspects of these two modalities, square nail and DCP plate, and to compare their results. For this, out of a total of 18 cases of forearm fractures, 13 were selected randomly and treated by O.R.I.F. with Talwalkar's square nail. Other 5 cases were treated by O.R.I.F. with small fragements DCP plates and 3.5mm cortical screws.

The overall average *operative time* noted in this series was 1 hrs 47min. Average operative time for Group I was 1hrs 40min and for Group II 1hrs 55min.

The use of *bone grafts* has been reported by many authors. Jinkins (1960) and Caden (1961) in their series of patients had reported use of bone grafts at the time of internal fixation in 30.3% and 11.5% cases respectively. Anderson et al (1975) used bone grafts in 25.9% of patients for fractures in which more than one third of the circumference of the shaft was comminuted.

In our series of cases, autogenous iliac cancellous bone grafts were used in 27.7% of patients at the time of internal fixation using the Anderson et al (1975) criteria, i.e. when the comminution involved more than one third of the circumference of the shaft of radius or ulna.

As regarding the *duration of post operative immobilization* Anderson et al (1975) in his series, used A/E POP cast for post operative immobilization in most of his cases. The average duration of POP cast immobilization in his series of cases was 7.6 weeks. He had suggested in his study that if there was minimum comminution of one or both bones, good anatomical alignment and fixation had been achieved, and the patient was intelligent and co-operative, no external immobilization was neccessary, but no strenuos activity was allowed till fracture had consolidated. But in cases with comminution, less than perfect reduction and internal fixation and poor cooperation of patient, he suggested that an A/E POP cast must be applied for six to eight weeks.

Similar criteria were aplied in our study, and all patients were given A/E POP slab immobilization till the sutures were removed which was replaced by A/E POP cast thereafter. The minimum duration of post operative immobilization was 6 weeks in Group I and 3 weeks in Group II. The maximum duration in Group I was 20 weeks and Group II was 12 weeks. The average duration of post operative immobilization in cases fixed with square nail (Group I) came out to be 12 weeks and 3 days, and in Group II (fixed with D.C.P.) it came out to be 7 weeks and 2 days. This was because anatomical alignment, compression at fracture site, and rigidity of fixation was better with D.C.P. in Group II.

As regarding *immediate post operative complications* Marek

(1961) reported one patient of fracture of upper 3rd of radius with transient motor paralysis of posterior interosseous nerve. Andreson (1975) reported five posterior interosseous nerve palsy cases when D.C.P. fixation was done in fracture through proximal part of radius. Four cases recovered in six weeks and one required full six months for recovery.

Similarly, in our study there was one, 7.7%, case of posterior interosseous nerve neuropraxia injury in Group I, and one, 20%, in Group II. The Group I patient had proximal 3rd fracture of radius and the paralysis recovered in 9weeks, and Group II patient recovered in 3 weeeks. Moreover, we encountered 1, 7.7%, case of tourniquet palsy in Group I which recovered completely in 12 weeks.

As regarding the *early complications*, which presented with in one week post operatively, in Group I there were 2 cases, 15.4%, of superficial infection which healed in 3 weeks. In Group II there was one case of superficial infection, a case with Grade I compound injury initially, which healed in 3 weeks.

This incidence was comparable to studies by Sage (1959) who reported 2 cases of superficial infection which responded to antibiotics and antiseptic dressings. Anderson (1975) also encountered few cases of superficial infection which healed with in 2 weeks.

As regarding the *late complications*, Anderson (1975) reported

(1983) encountered 5.4%, Burwell and Charnley (1964) 5.3%, Cady and Dodge (1972) 5.1% deep infections.

In our study in Group I, there was one case of deep infection, which led to acute osteomyelitis of both bones of forearm. This patient had Grade III compound injury initially. The incidence in Group I was therefore 7.7%. But there was no case of deep infection in Group II patients.

In Group I, there was one cases, 7.7% of olecrenon bursitis due to protruding proximal end of ulnar square nail. After the fracture union and consolidation, in this case of compound (Grade II) segmental fracture of ulna, the ulnar square nail was extracted and the bursitis subsided.

Dodge and Cady (1972) reported 4, 3.3%, cases of implant failure, in series of 119 cases of D.C.P. fixation, due to loosening of screws. There was one, 7.7%, case implant failure in form of breakage of ulnar square nail six months after its fixation, in Group I. There was no case of implant failure in Group II.

Marek (1961) treated 32 fractures of both bones of forearm with square nail fixation, achieved good results and formulated criteria for judging *anatomical results* in these cases from post operative and follow up radiographs. These criteria were modified and applied in our study. Marek (1961) had reported 4 cases, 12.5%, out of total of 32 cases of square nail fixation with poor anatomical alignment and poor func-

tional results.

Whereas in our study in Group I, there were 69.2% cases with good, 23% cases with satisfactory and 7.6% case with poor anatomical alingment. In Group II these were 80% good, 20% satisfactory and no poor anatomical results. Thus the anatomical results were better in Group II as compared to Group I.

Regarding the process of *fracture union*, Sage (1959) reported 6.2% non union in series of cases treated by intramedullary nail fixation. Caden (1961) reported 16.6% cases of non union in forearm fractures treated with intramedullary Rush pins. Marek (1961) reported a series of 32 patients treated by square nail fixation. He reported 4 cases, 12.5%, which went into delayed union and non union.

Anderson (1965) in his study on intramedullary nail fixation found that fracture union occured promptly in fracture which were fixed rigid after open reduction. Delayed union or non union occured when nail inserted was loose in marrow canal. Street (1986) reported 7% non union and 1.4% rate of delayed union in series of 137 cases treated by closed nail fixation.

According to Anderson (1973) criteria of fracture union, we had 1, 7.6%, infected non union in our Group I. There was no case of delayed union, where square nail fixation was used. The average time of union was 16 weeks and 3 days.

As regarding the rates of fracture union and fracture healing time with compression plate, there have been many studies

in literature. Anderson (1975) in their series of 244 patients treated by Muller's compression plates had 1.6% cases, which went into non union. The average time of union in his series was 7.4 weeks. Grace and Eversmann (1980) also used compression plate and reported 3.1% non union. Hadden (1983) used small fragment D.C.P. and reported 4% non union. Shah et al (1988) used small fragment D.C.P. and reported only 2.9% delayed and non union.

In Group II of our studies where small fragment D.C.P. was done there was no case of delayed or non union according to Anderson 1975 criteria. The average time of complete union was 14 weeks and 3 days but most of the cases, 60%, had fracture union by 9th week post operatively.

From his study in 1975 Anderson et al suggested that range of supination and pronation is the most significant indicator of the *quality of results* in fractures of forearm bones after the fracture had united. Only in few cases, the range of flexion and extension of wrist and elbow were affected in a significant manner so as to determine the quality of results. He suggested the criteria for assessing the the final quality of results which are described below :

Excellent : Union with excellent or (>75%) range of supination pronation and (>90%) range of flexion and extension at wrist and elbow.

Good : Union with >50% rotational arc and >80% flexion extension range.

Acceptable: Union with <50% rotational arc or <80% flexion and extension range.

Poor : Non union with or without loss of motion.

In his study he had 58.7% excellent, 30% good, 7.1% acceptable and 3.1% poor results.

In our study we have upgraded the range of maximum achievable rotational arc of forearm as 100% for excellent, more than 80% for good more than 60% for acceptable and less than 60% for poor results.

Using these modified criteria, we achieved *Excellent* results in 1 (7.7%) cases, *Good* results in 5(38.5%) cases, *Acceptable* in 4 (30.7%) cases and *Poor* results in 3 (23%) cases in Group I. In Group II, the results were better with, 2 (40%) *Excellent*, 1 (20%) *Good* and 2 (40%) *Accpetable* results. There was no case with *Poor* results in Group II.

The routine removal of implant after fracture consolidation, either with square nail intramedullary fixation or with DCP fixation, has not been recommended by any author. Removal of implant has been suggested only if it causes some problems. Most common indications have been, olecrenon bursitis due to protruded proximal end of ulnar square nail, restriction of movements of wrist when proximal end of radial square nail protrudes out . As regarding DCP, the subcutaneous location of the plate and repeated contusions of overlying tissue in some cases necessitates the removal of plate. Implant failure

is one other cause which would obviously necessiate the removal of implant either due to loosening of screws, or breakage of plate or breakage of nail due to metal fatigue.

Hidakas and Gustilo (1984) after a study of 32 plate removal suggested the protection of limb in A/E POP cast for 6 weeks after plate removal, so as to prevent the occurence of refracture.

Bednar and Grandwiewisky (1992) suggested that plate removal must not be done earlier than 2 years after application of the plate, so as to minimize the chances of refracture.

In our Group II, during the follow up after fracture union, there were no complaints by patients due to the implant. Thus plates were not removed in any case on our series.

In Group I, during follow up, there were three cases where nails had to extracted. In one patient the protruded end of ulnar nail was causing olecrenon bursitis. The fracture had consolidated, therefore, the ulnar nail was removed and an A/E POP cast was applied for 6 weeks.In other patient, there was a deep infection which led to acute and later on to chronic osteomyelitis of both bones of forearm with two discharging sinuses. This case later on developed infected non union of fractures of both bones. In this case, radial and ulnar nails were removed, sinus were curreted and A/E POP cast was applied.

There was a third case where ulnar nail suffered fatigue breakage, approx. 6 months after operative intervention. In this case ulnar nail was replaced with a new nail, bone grafting was done

and A/E POP cast immobilization was given . The fracture of bone united thereafter and patient again achieved acceptable functional results.

CONCLUSION

CONCLUSION

Eighteen cases of fracture of both bones forearm, admitted in OPD or emergency department of M.L.B. Medical College, Jhansi, were included in this study. From these cases, few were selected randomly, treated by both bone square nail fixation, after open reduction and were designated as Group I. Other cases were treated by both bone DCP fixation after open reduction, and were included in Group II.

The following conclusions were drawn from the study :

1. *Age and sex of patients* :Young (20-40 years) active adults, who more often get involved in outdoor work, were most commonly (66.6%) affected by this fracture.

2. *Mode of injury* : Road traffic injury was the single most common (44.4%) cause of trauma resulting in the fractures of both bones forearm. Females comprised of only 15% of the total cases.

3. *Occupation* : Most of the patients (33.3%) were poor farmers or daily wage labourers in our study.

4. *Side and site of fracture* : Both sides were involved with similar frequency and mid 3rd was the most common part (77.7%) of forearm to be fractured.

5. *Type of fracture* : Transverse fracture pattern was found to be the most common (63.8%) fracture pattern.

6. *Nature of study* : Most of the cases (77.7%) had simple fracture.

7. *Associated injury* : Most of the patients (72.2%) had no associated injuries. 16.6% cases had fracture of some other long bone as well.

8. *Interval between injury and operation* : Most of the patients were operated with in 0-2 weeks of injury.

9. *Operative intervention done* : Patients were randomly selected and intramedullary nail fixation was done in 72.2% cases and DCP fixation was done in 27.7% cases.

10. *Bone grafting* : Iliac cancellous bone grafts were used at the time of internal fixation when the comminution involved more than 1/3rd of the circumference of the shaft of radius or ulna or when fracture was more than 4 weeks old. According to these indications bone grafting was done in 27.7% cases in our study.

11. *Duration of post operative immobilization* : This was significantly less in case with DCP fixation (average 7 weeks 2 days) as compared to cases treated by square nail fixation (average 12 weeks and 3 days).

12. *Quality of fixation* : Anatomical alignment, compression at fracture site and rigidity of fixation was better with DCP than with square nail fixation.

13. *Radiological follow up* : Fracture callus was minimal with

DCP fixation but abundant with sqaure nail fixation. Although the fracture callus appeared at approximately the same time post operatively but the consolidation and maturation of callus leading to fracture union was more rapid and swift where DCP fixation was done. Average time of fracture union was 16 weeks and 3 days where square nail fixation was used and 14 weeks and 3 days where DCP fixation was used.

14. *Functional results* : The range of rotational movements (supination and pronation) at forearm, achieved after fracture union and a short course of mobilization excercises, was significantly better in cases where DCP fixation was used as compared to cases where square nail fixation was used.

15. *Final evaluation* : Taking the fracture union and rotational movements of forearm and rehabilitation of the patient into consideration, the overall quality of results was better with DCP fixation as compared to square nail fixation.

16. Other important conclusions which can be drawn from this study are :

(a) Results were better in simple fractures than compound fractures.

(b) Results were inferior when there was comminution at fracture site.

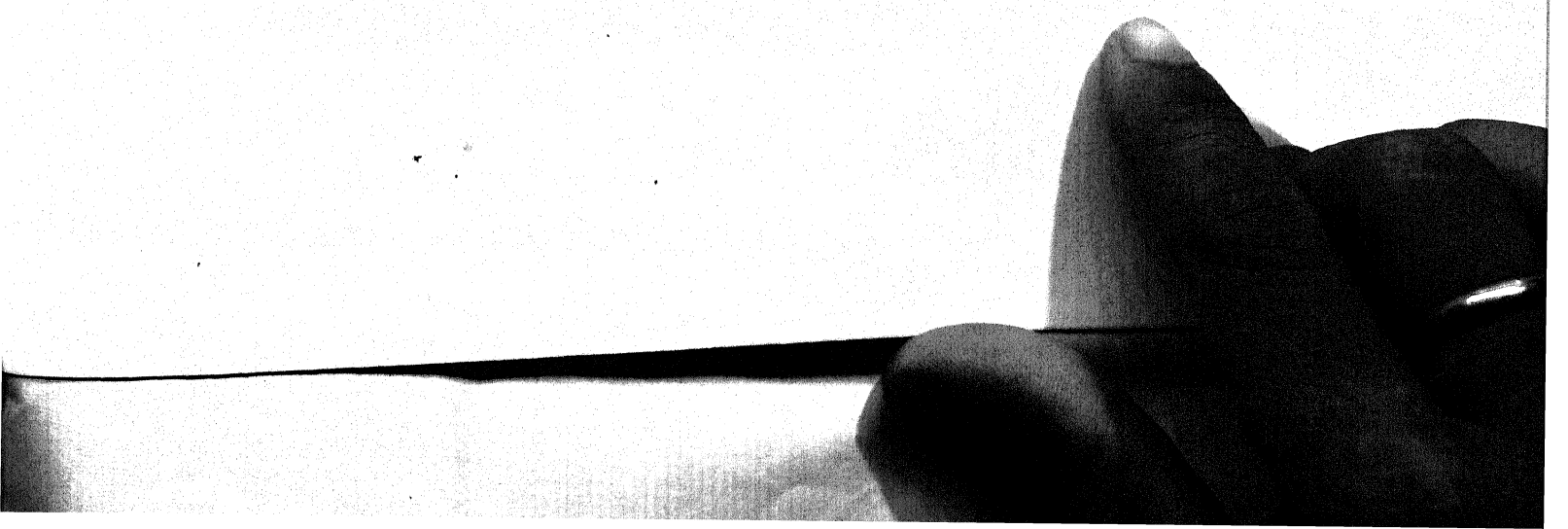
(c) Better results were obtained in fractures through mid 3rd, without any comminution, as compared to upper or lower 3rd.

(d) Regardless of type of implant used, the functional results were inferior when duration of post operative immobilization was prolonged.

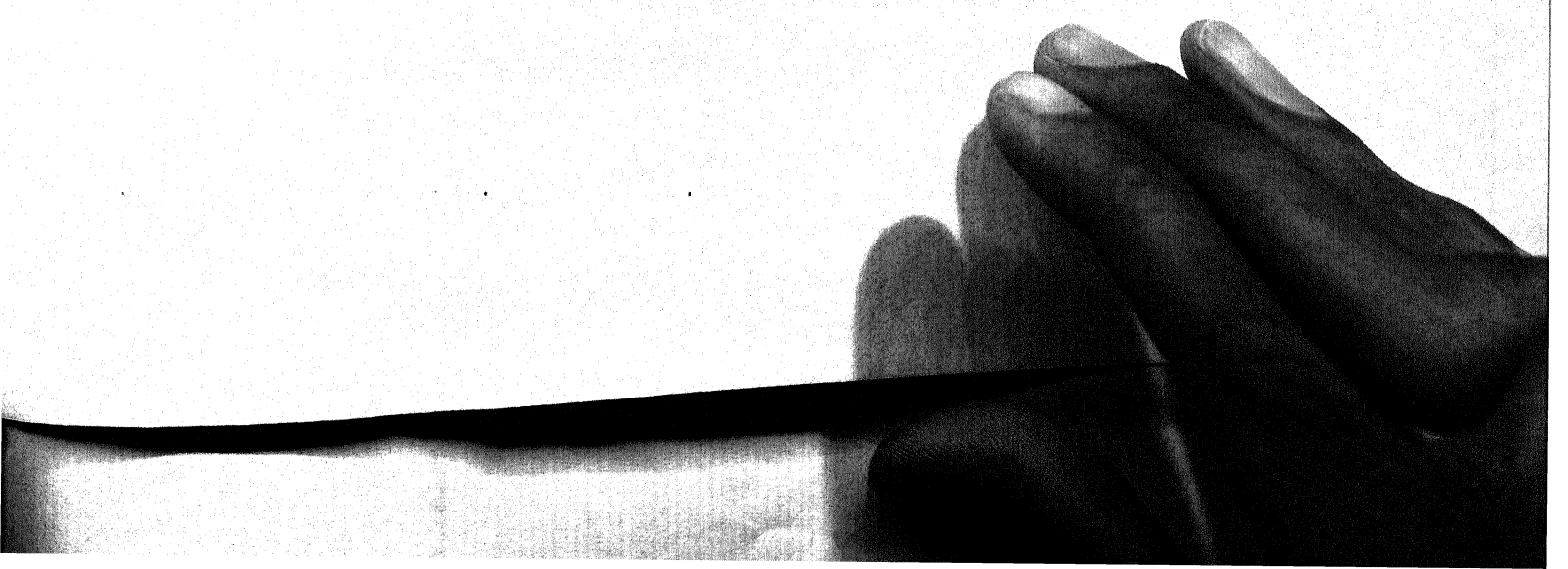
(e) There were increased chances of posterior interosseous nerve neuropraxia when fracture of upper 3rd of radius was being exposed.

(f) For segmental fractures of radius and, or, ulna, intramedullary nail fixation was a better technique.

(g) There was a very good role of unreamed square nail fixation, as an emergency procedure, in cases of severly compound injuries of forearm, where good splintage was provided by these nails while soft tissue healing occured.



SUMMARY



SUMMARY

The management of forearm fractures has always been a test to the skills of the orthopaedic surgeon. Radius and ulna function as a unit like two wheels of cart. Maintaining axial and rotational alignment of both the bones and preserving the interosseous space during their reduction for treating their fractures, is essential for achieving proper functional results with good range of supination and pronation of forearm. There is inherent difficulty in reducing and maintaining the reduction of these two parallel bones due to the presence of strong supinating and pronating muscles.

Since time immemorial these fractures have been managed by correction of clinical deformity and application of wooden splints. Plaster of paris (POP) was introduced by Majithsen in, 1852, but was used for forearm fractures by Bohler in, 1929, for the first time. Later on detailed studies by Knight and Purvis (1949), Holdsworth (1949), Smith (1956) proved that closed reduction and external immobilization by POP cast resulted in high incidence of unsatisfactory results.

Due to unpredictable results and hazards of prolonged immobilization various workers studied and experimented with various techniques of internal fixation after open reduction with a variety of implants. The use of intramedullary implant for internal fixation was develped by Heygroves (1918), Lambrinudi (1939) and Kuntcher (1940). Rush and Rush (1937 and 1939) reported use of Stienmänn's pin for intramedullary internal fixation of

fractures of forearm bones. In 1959, Sage, introduced triangular forearm nails and reported good results with these nails. Talwalker (1964) improvised rigid solid square nails for radius and ulna and reported good results after using them.

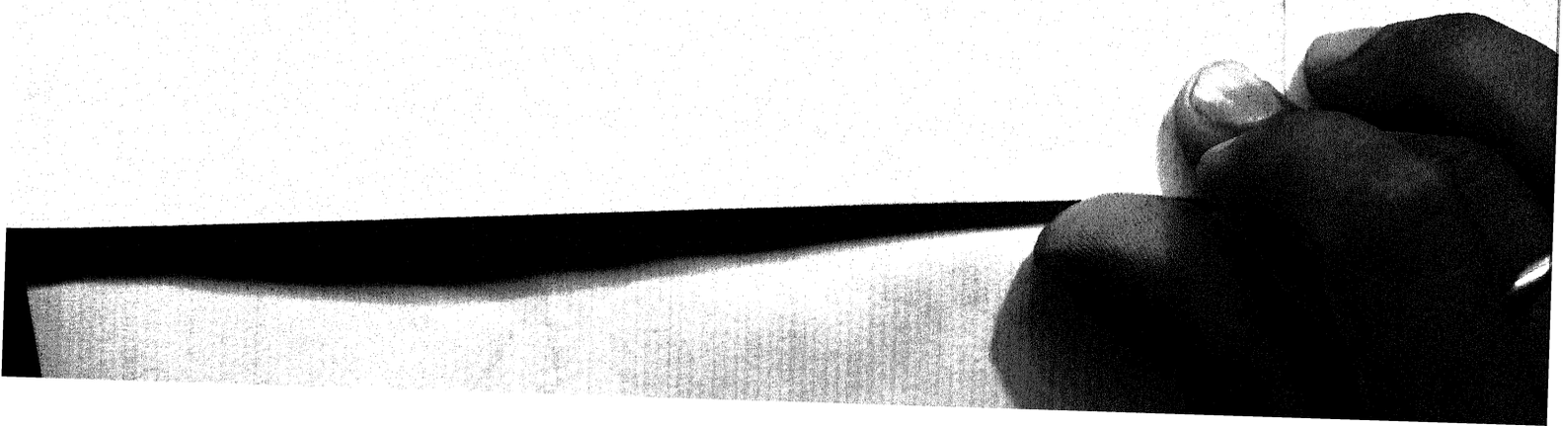
The concept of treating diaphyseal fractures of both bone forearm with plates and screws was given by Lane (1906) and Lambotte (1907) but failures were frequent due to metal reaction and inadequate designs. Shermen (1913) introduced vanadium steel plate, Campbell and Boyd (1941) used autogenous tibial grafts as plates but failures were still common. The concept of compression at fracture site with the help of coapting screw was given by Danis (1949), Bagby and Janes (1958), but it was Muller's or AISF compression device used with Muller's plate developed by Muller, Allgower and Willineger (1961) which became very popular and is being used even now days. The dynamic self compressing plate (DCP) which obviated the need of seperate compression device and needed less extensive dissection was developed by Allgower (1970) and this plate has been used in our study. These DCP were used successfully by Anderson (1975), Grace and Everemann (1980), Hadden (1983) and many others. Further advanced design of DCP named as Limited contact-Dynamic compression plate (LC-DCP) was developed by Perren et al in 1989.

Nowdays, square nail is the most popular intramedullary fixation device and DCP is the most commonly used plate with screws, used for fixing fractures of forearm bones. But, the specific

indication and quality of results with these two type of implants has not been clearly mentioned in literature. Thus we started with our present study to evaluate and compare the results of DCP versus intramedullary square nail in fractures of both bones of forearm. A total of 18 cases were included in this study from which 13 patients, after random selection, were treated by intramedullary square nail and 5 patients were treated by DCP fixation. Standard surgical techniques were used for operative open reduction and internal fixation. Henry's approach was used for exposing fractures of distal 2/3rd of radius and Thompson's approach was used for fractures of proximal 1/ 3rd of radius. Ulna was exposed by posterior subcutaneous approach. Radius and ulna were then internally fixed with either DCP or square nails, same implant being used for both the bones, according to standard techniques.

Patients were studied from the day of their admission through, pre, intra and post operative period to complete follow up with clinical and radiological assessment at successive visits till the patient achieved maximum possible functions of the injured limb. The data thus collected from patients of these two groups was analysed, evaluated and compared with each other. The quality of results and incidence of complications with these two type of implants were found to be similar to different studies by various authors. Then we went ahead to pursue the final aim of this study, i.e. to compare the results of DCP and intramedullary square nail fixation and to suggest their specific indications.

We used modified Anderson 1975 criteria for evaluating the quality of results in individual cases of our study, and finally we could conclude, that, anatomical alignment compression at fracture site and rigidity of fixation was better with DCP then with square nail fixation. Fracture union occured swiftly and early, functional results were significantly better and the overall quality of results was better with DCP fixation as compared to square nail fixation. Few other important facts which came to light in this study were that, results were better when fracture was closed or simple, when there was no comminution at fracture site and when the duration of immobilization was short. Moreover this study also proved the excellent role of square nail fixation in segmental fractures of forearm bones.



BIBLIOGRAPHY

BIBLIOGRAPHY

1. Allgower M, Perren S and Matter P (1970) : A new plate for internal fixation - The dynamic compression plate (DCP). Injury 2: 40

2. Anderson LD, Sisk TD, Toms RE and Park W.I. III (1975) : Compression plate fixation in acute diaphyseal fractures of the radius and ulna. JBJS ; 57-A : 287.

3. Anderson LD(1965) : Compression plate fixation and the effect of different types of internal fixation on fracture healing. JBJS; 47-A : 191-208.

4. Anderson LD and Bacastow DW (1984) : Treatment of forearm shaft fractures with compression plate. Contemp. Orthop. 8 : 6(17).

5. Bagby GW and Janes JM (1958) : The effect of compression on the rate of fracture healing using a special plate. Am J Surg 95 : 761-771.

6. Bagby GW (1968) : Clinical experience of simplified compression bone plate. Am Jour Orthop Surg; 10:302.

7. Bagby GW, Janes JM (1957) : An impacting bone plate proceedings of staff meetings of the Mayo Clinic; 32 : 55.

8. Baker GI,Burkhalter WE, Barclay WA and Eversmann WW (1969) : Treatment of forearm shaft fractures by long slotted plate. JBJS 51-A(5) : 1035.

9. Bednar DA, Grandwiewisky : Complication of forearm plate removal. Can J Surg 1992; 35: 428.

10. Benzamin A (1982) : Injuries of the forearm, Watson-Jones fracture and joint injuries. Sixth ed. 666.

11. Boreau amnd Herman (1952) : Role of compression in fracture healing. Am J. Surj 63 : 648-653.

12. Bradford CH, Adams RW and Kilfoyle RM (1953) : Fractures of both bones of the forearm in adults. Surg Gynaec and Obstet. 96: 240.

13. Burnell HN and Charnley AD (1964) : Treatment of forearm fractures in adult with particular reference to plate fixation. JBJS 46-B; No-3.

14. Caden JG (1961) : Internal fixation of fractures of forearm. JBJS; 43-A: 1115.

15. Campbell EC and Boyd HB (1941) : Fixation of onlay bone grafts by means of vitallium screws in the treatment of unusual fractures. Am J Surg; 51 : 748-56.

16. Chapman KW and Frankel VH (1973) : Rotational de-

formity of both bones following forearm fractures. JBJS 55-B, 666.

17. Charnley J : The closed treatment of common fractures, First editon, Edinburgh, London and New York (1950), Churchill Livingstone.

18. Charnley J (1957) : Closed treatment of common fractures. Second edition, Edinburgh and London, E&S, Livingstone Ltd.

19. De Buren N (1962) : Causes and treatment of non-union in fractures of the radius and ulna. JBJS 44-B; 614.

20. Denham RA (1969) : Compression and coaption. JBJS 51-B; 177.

21. Dodge HS and Cady GW (1972) : Treatment of fractures of the radius and ulna with compression plates. JBJS; 54-A : 1167-1176.

22. Dykes RG (1976) : Plating of forearm fractures. JBJS; 58-B, No-3: 383.

23. Eggers GWN (1948) : Internal contact splint. JBJS; 30-A: 40.

24. Eggers GWN, Shindler TO and Pomerat CM (1949) : The influence of the contact compression factor on

osteogenesis in surgical fractures. JBJS; 31-A : 693-716.

25. Eggers GWN, Shindler TO and Pomerat CM (1951) : Clinical significance of contact- compression factor in bone surgery. Arch Surg 62 : 467.

26. Erichsen JE (1884) : The science and art of surgery. 8th Edition, London.

27. Evans EM (1951) : Fractures of the radius and ulna, JBJS; 33-B : 548.

28. Grace TA and Eversmann WW (1976) : The management of segmental bone loss associated with forearm fractures. The proceedings of the Western Orthopaedic Association, JBJS; 58-A : 283.

29. Grace TA and Eversmann WW (1980) : Forearm fractures : Treatment by rigid fixation with early motion. JBJS; 62-A, No-3: 433.

30. Hadden WA, Eschauer R and Segel W (1983) : Results of AO Plate fixation of forearm shaft fractures on adults. Injury 15: 44-52.

31. Henry AK : Exposures of long bones and other surgical methods. Bristol, England (1927). John Wright

and Sons, Ltd.

32. Hermann et al (1943) ; Treatment of fracture of radius and ulna by open reduction and internal fixation. Arch Surg 52 : 627.

33. Hey Grovers, EW (1918) : Ununited fractures with special reference to gun shot injuries and the use of bone grafting. Brit J Surg; 6: 205.

34. Hicks JH (1961) : Fractures of the forearm treated by rigid fixation. JBJS; 43-B : 680.

35. Hidakas and Gustilo RB (1984) : Refractures of bones of forearm after plate removal. JBJS; 66-A : 1241.

36. Holdsworth (1949) : Treatment of forearm bone fractures. Am. J. Surg. : 47; 248.

37. Hugston JC (1957) : Fractures of the distal radial shaft. Mistakes in management. JBJS; 39-A : 249.

38. Hotckiss RN, Sowa DT : An anatomic and mechanical study of the interosseous membrane of the forearm. J Hand Surg 14-A : 256-261. 1989.

39. Jinkins WJ, Jr Lockhart LD and Eggers GWN (1960) : Fractures of the forearm in adults. Southern Med Jr 53 : 669-679.

40. Knight PA and Purvis GD (1940) : Fractures of both bone of forearm in adults. JBJS; 31-A : 755-64.

41. Klace and Perren (1982) : Fixation interne des fractures / ensemble plaque- vis a compression conjuguee (DCU). Helv Chir Acta 49 : 77-80.

42. Lambrinudi C (1939) : Intramedullary Kirschner wires in the treatment of fractures. Proc Roy Soc Med London; 33 : 153.

43. Lam SJ (1964) : The place of delayed internal fixation in the treatment of fractures of the long bones. JBJS; 46-B : 393.

44. Lambotte A (1993) : Chirurgie operators des fractures, Paris, Masson.

45. Lane WA (1900) : The treatment of simple fractures by operation. Lancet 1 : 1489-93.

46. Marek FM (1961) : Axial fixation of forearm fractures. JBJS Vol; 43-A : no-8.

47. Mathews LS et al (1982) : The effect on supination pronation of angular malalignment of fractures of both bones of forearm. JBJS (Am) 64-A (1) : 14-7.

48. Mckibbin B (1978) : The biology of fracture healing in long bones. JBJS 60-B : 150.

49. Michels C and Weissman SL (1976) : Intramedullary nailing in fractures of the foream. JBJS; 58-B, No-3 : 380.

50. Muller ME, Allgower M and Willeneger H (1970) : Mannual of interval fixation. New York, Springer- Verlag, Inc.

51. Muller ME, Allgower M and Willeneger H (1965) : Technique of internal fixation of fractures. New York, Springer.

52. Muller ME (1961) : Principles d' Osteosynthese'. Helv Chr Acta 28 : 198.

53. Naiman PT, Schein AJ and Siffert RS (1970) : Use of compression plates in selected shaft fractures of the upper extremity : A preliminary report. Clin Orthop 71 : 208-216.

54. Patric J (1946) : A study of supination and pronation, with special reference to the treatment of forearm fractures. JBJS; 28 : 737-748.

55. Perren Sm, Klauek, Frigg R (1989) : The concept of biological plating : The limited contact dynamic compression plate (LC-DCP) Orthop Trauma 94 : 56-61.

56. Petxie D (Halifax NS) and Tile M (1972) : Fractures of the radius and ulna - an end result study following the use of compression plates. JBJS; 54-B, No-4(v) : 762.

57. Rand JAMD, Kai Nan An Ph.D., Edmund YS, Chao Ph.D. and Petric J, Kelly MD (1981) : A comparision of the effect of open intramedullary nailing and compression plate fixation on fracture site blood flow and fracture union. JBJS; 63-A : 427.

58. Ritchie SJ, Richardson JP and Thompson MS (1958) : Rigid medullary fixation of forearm fractures. Southern Med J; 51 : 852-856.

59. Ritchie DM (1968) : A method of fixing forearm fractures. JBJS; 50-B, No-3.

60. Rosaker and Kopta (1981) : An evaluation of operative treatments for fractures of bones of forearm. Acta orthop Scand 43 (19) : 214-8.

61. Rush LV and Rush HL (1937) : A reconstruction operation for communited fractures of the upper third of the ulna. Am J Surg; 38 : 332.

62. Sage FP (1959) : Medullary fixartion of fractures of the forearm. A study of medullary canal of the radius

and a report of fifty fractures of the radius, treated with prebent triangular nail. JBJS; 41-A : 1489-1516.

63. Sargent JP and Teipner WA (1965) : Treatment of forearm of double plating : A preliminary report. JBJS; 47-A, No-8.

64. Sarmiento A, MD Cooper, JSMD and Spunclair WF DPO (1975) : Forearm fractures : Early functional bracing : A preliminary report. JBJS; 57-A : 297.

65. Schenk R, Willenegger H (1967) : Morphological findings in primary fracture healing : Symposia. Biologica Hingarica. 8 : 75-86.

66. Schemitsch Eh and Richards RR : The effect of malunion on functional outcome after plate fixation of both bones of forearm in adults. JBJS, 74-A : 1068-1078, 1992.

67. Schnute WJ (1962) : Fractures of the forearm : Principles of treatment. JBJS. 44-A, No-8 : 1668.

68. Shah KM, Divetia Pankaj A, Khamar RM (1988) : Management of Diaphyseal fractures of forearm bones - An evolution. Clin Orthop India; 3 : 51.

69. Sisk T David : Fractures Campbell's operative Orthopaedics. 6th edition, Vol-1; 1980 : 508.

70. Smith Hug and Sage FP (1957) : Medullary fixation of forearm fractures. JBJS 39-A : 91-98.

71. Smith JEM (1959) : Internal fixation in the treatment of fractures of the shafts of the radius and ulna in adults. The value of delayed operation in the prevention of non-union. JBJS, 41-B, No-2 : 122.

72. Smith JEM (1964) : The results of early and delayed internal fixation of fractures of the shaft of the femur. JBJS 46-B : 28.

73. Stewart MJ (1958) : Internal fixation - Intramedullary fixation of forearm fractures. American Academy of Orthopaedic Surgeons. Instructional course lectures. 15 : 49.

74. Street DM (1951), Spectator letter (1955), Venable CA : An impacting bone plate to attain close opposition. Ann Surg; 133 : 808-812.

75. Street DM (1986) : Intramedullary forearm nailing. Clin Orthop. Nov 212 : 219-30.

76. Stuck WG and Thompson MS (1949) : Treatment of fractures of forearm with intramedullary pins. Am J Surg; 77 : 12-18.

77. Talwalkar AK (1964) : Treatment of simple fractures of radius and ulna with internal fixation without external support. Kini Oration, Bombay, India.

78. Thompson JE (1918) : Anatomical methods of approach in operations on the long bones of the extremities. Ann Surg; 68 : 309.

79. Vainiopa S et al (1987) : Internal fixation of forearm fractures in children. Acta Orthop Scand 58(2):121-3.

80. Whiteside LA and Lesker PA (1978) : The effects of extraperiosteal and subperiosteal dissection on blood flow in the muscles. JBJS 60-A : 23.